SPECIAL TIME EDITION

THE SCIENCE OF CREATIVITY

Imagination at Every Age / The Power of Sleep / Your Inner Genius

TIME

SPECIAL EDITION

THE SCIENCE OF CREATIVITY

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Parts of this edition appeared previously in TIME.

STRIVING FOR THE NEW

OTHER CREATURES MAY BE BIGGER OR BADDER, BUT ONLY PEOPLE IMAGINE POSSIBILITIES—AND MAKE THEM HAPPEN

BY RICHARD JEROME

ARE YOU CREATIVE? IT'S A QUESTION MANY OF US have heard at some point in our lives, and whether we've answered it with hubris, hesitation or humility, our reply was likely informed by some common preconceptions about the very notion of creativity. The term carries a kind of mystical aura, its special power imbued with a touch of the divine. After all, creativity supplies the first verb of the Bible—"In the beginning, God created . . ."—and, of course, the deity itself is alternatively dubbed the Creator, nowhere more famously than in the Declaration of Independence, in which He/She endows us with those "certain inalienable rights." Advocates of intelligent design survey the universe, marvel at the exquisite celestial choreography and—even if they do believe in science and the big-bang theory of cosmogenesis—insist the stars, galaxies, planets and moons could never have sprung up solely through some spontaneous, random event. Closer to home, they say, terrestrial geology, flora and fauna—including our own elegant, if fatally flawed, physiology—can't be the result of a mere accident. Only a supreme genius could have imagined it all and set the whole thing in motion.

Yet for all its metaphysical and theological overtones, creativity is also the most fundamentally

The splattered floor in East Hampton, N.Y., where Jackson Pollock (1912–56) created his Abstract Expressionist paintings

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human of qualities. It is, in fact, "the unique and defining trait of our species," writes the Pulitzer Prize–winning biologist Edward O. Wilson in his book *The Origins of Creativity.* As Wilson frames it, creativity is "an innate quest for originality," driven by the enduring human passion for novelty, "the discovery of new entities and processes, the solving of old challenges and disclosure of new ones, the aesthetic surprise of unanticipated facts and theories, the pleasure of new faces, the thrill of new worlds."

University of Notre Dame anthropologist Agustín Fuentes, author of *The Creative Spark: How Imagination Made Humans Exceptional*, puts it this way. "In a nutshell," he says, "the essence of creativity is to look at the world around us, see how it is and imagine other possibilities that are not immediately present or based on our immediate personal experience. Creativity is seeing the possibilities and then trying to make those imaginings into material reality."

To be sure, no other species can lay claim to our capacity to devise something new and original, from the sublime to the sublimely ridiculous. Other animals do build things—birds assemble their intricate nests, beavers construct dams, and ants dig elaborate networks of tunnels. "But airplanes, strangely tilted skyscrapers and Chia Pets, well, they're pretty impressive," Fuentes says, adding that from an evolutionary standpoint, "creativity is as much a part of our tool kit as walking on two legs, having a big brain and really good hands for manipulating things." For a physically unprepossessing primate, without great fangs or claws or wings or other obvious physical advantages, creativity has been the great equalizer—and more—ensuring, for now, at least, the survival of *Homo sapiens*.

"Creativity is as much a part of our tool kit as walking on two legs and having a big brain."

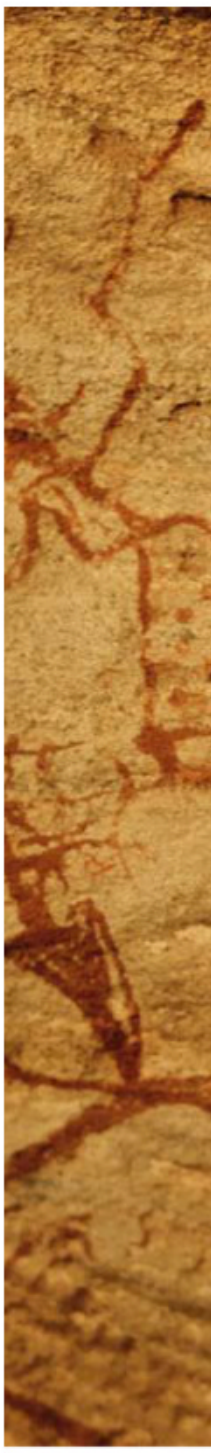
—anthropologist Agustín Fuentes

Still, even if we acknowledge that creativity and innovation are uniquely human, people tend to think creators—or "creatives," as they're now known in the professional world—are, if not divine, then members of a special rarefied class. Even more narrowly, creativity is often stereotyped as the province of artists. Painters, from Giotto to Leonardo and Michelangelo to Rembrandt and Vermeer, the French Impressionists, Picasso, Pollock, Basquiat, Banksy. Or poets and writers from Homer to Shakespeare, to Dickens, George Eliot, Proust and Borges. Or the great composers, filmmakers, actors and dancers. Flamboyant figures, perhaps, passionate, dramatic, bohemian in dress and attitude.

That's the caricature, at least. But some of the world's most illustrious "creatives" wore lab coats or never picked up a brush or pen except to scrawl numbers and formulas. Copernicus, Galileo, Newton, Einstein, Nash, Hawking, who all saw the universe in some new way; Darwin, Mendel, Curie, Watson and Crick—who mapped human evolution, discovered new elements and cracked the genetic code. Or the inventors, from Archimedes to Gutenberg, Watt, Whitney, Bell, Edison, Tesla and Jobs, along with untold researchers who labored obscurely in the employ of large companies and industrial labs. Indeed, although the concept of creativity conjures all-star lineups stacked with historical heavyweights, it's a mistake to become wedded to the Great Man or Woman theory of human innovation.

"People pigeonhole creativity as belonging to a single individual or a group of geniuses," Fuentes says. "They don't realize that each and every human has this incredible capacity to imagine and to change things. Auto mechanics can be amazingly creative—so can people trying to stretch a paycheck to the end of a month." In a business context, think of a publication like this one—or maybe a website or an ad agency. The design and editorial teams may reap all the creative kudos and cachet—but let's put in a good word for Mary Ellen in Finance, who figured out novel ways to make all that spellbinding prose and imagery come in under budget without sacrificing quality.

Some of humankind's most creative achievements have served seemingly quotidian, utilitarian ends—beginning, perhaps, with stone tools discovered in Africa that date back some 1.8 million years. "No living thing on the planet has ever thought to take a rock and modify it in certain ways so that it becomes a successful tool," Fuentes says. "You look at these old stone artifacts and you can see them as the iPhones of 2 million years ago." Several hundred thousand years later, societies were grinding up ocher and painting themselves as well as their tools—and, eventually, adorning the walls of their caves with figures and scenes—the origins of art and the peculiarly human drive to create purely

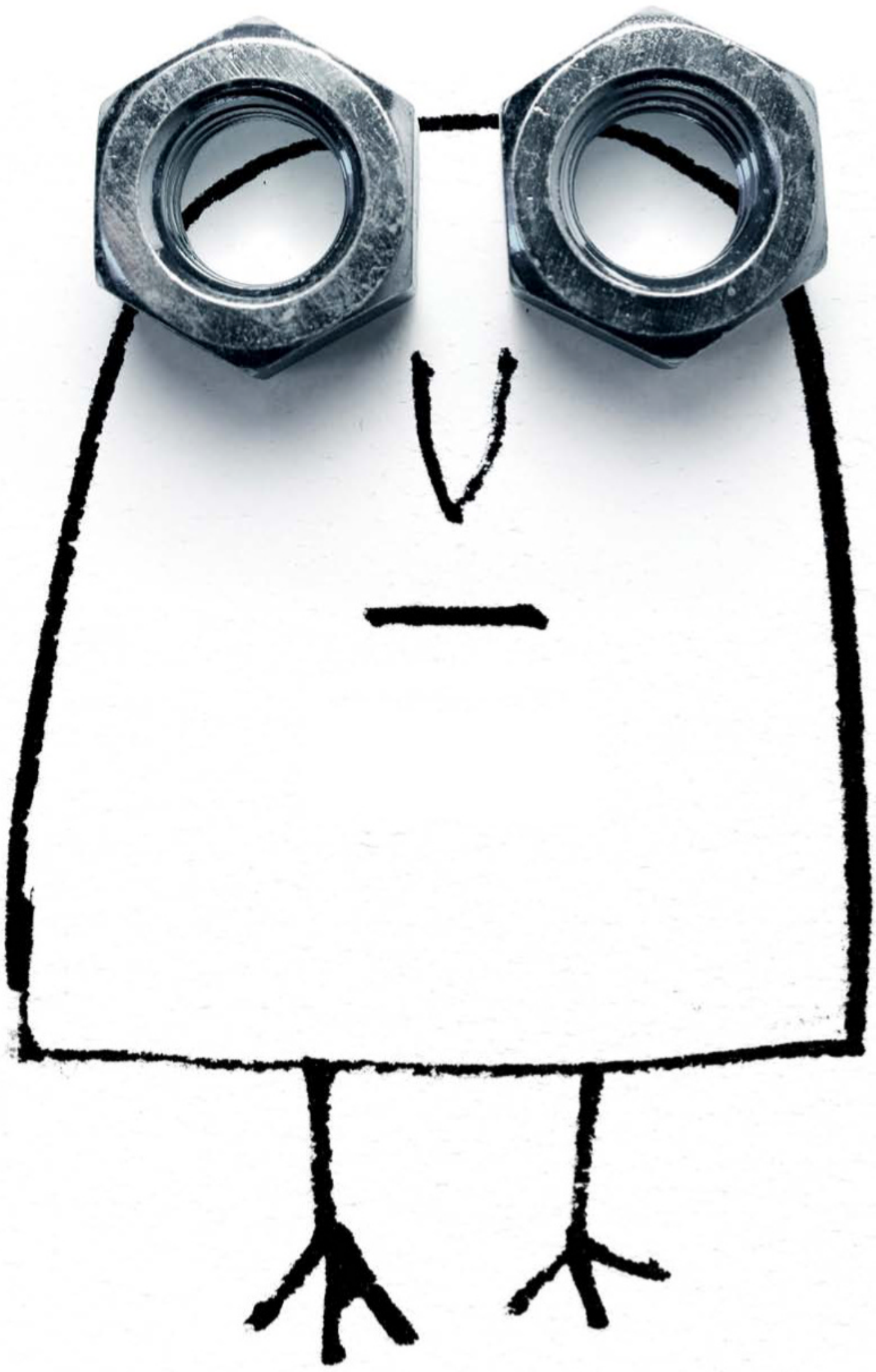


The evolution of imaging, from (left) cave paintings of hunting or fighting in Africa's Sahara region that date back as far as 40,000 B.C. to (right) a computer-generated depiction of the DNA double helix

for the sake of aesthetic pleasure. In other ways, utilitarian items evolved into objects of sensual delight. Animal skins into haute couture; meat—cooked by that newfangled thing called fire—into filet mignon. Language, from basic communication tool into *One Hundred Years of Solitude* and *Fifty Shades of Grey*.

In this TIME special edition we explore human creativity from a range of angles, delving into its neurological underpinnings in the brain as well as its relation to the psyche. We'll touch on many notable creators, past and present—highlighting, for example, Leonardo da Vinci, the ultimate Renaissance man and the subject of a 2017 biography by Walter Isaacson. This and other chapters offer up ways to learn from great creative minds and apply those lessons to tap into your own imaginative reservoir.

That points to another key to human creativity: its essentially derivative and collaborative nature. As authors Anthony Brandt and David Eagleman point out, creators manipulate and reconfigure existing ideas and forms; the most breathtaking art, science and other innovations don't spring forth from a vacuum. All creators, even the most celebrated ones, draw on the work of others, influenced consciously or not by what's come before—and what's happening around them. "That capacity to think together, to imagine possibilities and to hope," Fuentes says, "that's what got us here."



CHAPTER ONE

THE CREATIVE ANIMAL

THE IMPULSE TO INVENT AND INNOVATE IS AN INTEGRAL PART OF BEING HUMAN

"Creativity is the art of combining a little idea with another little idea, you may have another little idea, and so on . . . at the end maybe a great idea will come up."

—Serge Bloch

Bloch is a French illustrator whose iconic work has appeared in newspapers and magazines around the world—and appears at left. He has also illustrated and written several books and received two gold medals from the Society of Illustrators.

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THIS IS YOUR BRAIN ON CREATIVITY

WHAT NEURAL NETWORKS UNDERLIE THOSE "AHA" MOMENTS OF INSPIRATION AND INVENTION?

BY JEFFREY KLUGER

DON'T BE TOO AWED BY THE WONDER OF CREATIVITY. Much of it is simply moving matter around—a bit of clever rearranging. A Chippendale cabinet is nothing more than a transformed tree. The landscape artist, even a Van Gogh or Monet, did not invent the flowers—he just ran with them. And the most succulent hunk of beef bourguignonne you ever whipped up seems a lot less remarkable when you accept that somebody already spotted you the cow. You were not responsible for creating so much as a single molecule in your final product.

But what about the ideas that guided the way you manipulated that matter? The shape the cabinet would take—its whorls and lines and its final umber color materialized in a brain before they materialized in the world. The same is true of the lines of a sonnet or the chords in a symphony or the vision of what *Sunflowers* should look like before it looked like anything at all to anyone but Van Gogh himself.

At the Drexel University EEG Lab, elastic caps are rigged with multicolored EEG electrodes to help map the thinking brain.

The source of such inspiration has long stymied scientists. We're all born with more or less the same brain, and we all use it in more or less the same way, but people we call creative seem able to summon up something else—insight from the ether, music from the void. There is no such ether, of course, and by definition, a void is a void. It's the brain, at bottom, that is the seat of all creativity.

Somewhere in the 100 billion neurons and the 100 trillion connections they form are the lines of neural code that gave us *The Nutcracker*, *Huckleberry Finn*, the Saturn V rocket and every other bit of artistry or invention human beings have ever summoned up. Increasingly—thanks to better imaging techniques, a deeper understanding of the interplay of brain regions and more—scientists are learning how to trace the creative insight back to its

source, understand what sparked it and figure out why that spark happens more often in some of us than in others.

"Some people think that creativity should be like magic," says experimental psychologist Mark Beeman of Northwestern University. "But scientists are becoming better able to trace it to its precursors—to what was responsible for what we experience as an insight or 'aha' moment."

One of the most important steps in figuring out how creativity works is to understand how it *doesn't* work. Popular wisdom in recent years has held that the brain's two hemispheres neatly divide the day's tasks. The left brain, so the thinking goes, is the serious brain—critical, analytical, skeptical, mathematical. It's also where language lives. The right brain, by contrast, is the wild child—artistic, abstract, insightful, intuitive. That's not quite right.

For starters, one of the brain's great features is its redundancy, its ability to create workarounds or to share tasks. Although it's true that one brain region may be principally responsible for certain functions—the left hemisphere does do more of the heavy lifting when it comes to language—there's also a lot of load distribution across brain structures.

That's especially true of creativity. Beeman and his colleague John Kounios, a professor of applied cognitive and brain sciences at Drexel University, have investigated the creative process, using functional magnetic resonance imaging (fMRI) and high-density electroencephalography (EEG) to watch the brain as it sorts though a problem.

"We've been able to map the 'burst of enthusiasm' when the solution to a problem 'pops into consciousness.'"

—John Kounios, brain-sciences professor at Drexel University

The particular problem Beeman and Kounios chose for their study was what is known as a remote association test, in which subjects are given three seemingly unrelated words and asked to determine a third word with which they could each be paired. Some are very easy: "loser, throat and spot" can all be paired with "sore." Some are harder: "pine, crab and sauce," for example, share "apple." Some are harder still, like "wise, work and tower," which share "clock."

There are two ways to solve any of these puzzles. One is to think it through deliberately, rigorously, pairing up one word with a possible answer ("pine" with "cone," say) and seeing if it works with the others (in this case, nope). The other, the seemingly magical way, is simply to stare at the words, let them roll around in your head until—*bang!*—the answer presents itself. Psychologists label those twin approaches the analytical and the intuitive, and it's no contest that the intuitive feels better, more exciting—more creative. The brain arrives at the answer and gives itself—and you—a reward in the form of a sense of surprise and satisfaction.

"You solve a problem and you have this burst of enthusiasm," says Kounios (seen at right).

He and Beeman were able to map how all that happens. During the studies, the subjects were shown the three test words and were told to press a button and announce the solution as soon as they had it and to press another button to indicate whether they arrived at it analytically or intuitively. When the answer was intuitive, about a third of a second before the subject pushed the answer button, the EEG picked up a burst of gamma-wave oscillations above the right ear. The fMRI pinpointed that activity in the right inferior-superior temporal gyrus.

That region of the brain has a role in a number of processes, including language; it also helps mediate the neurology of the reward experience. The gyrus, it seems, was working on the problem all on its own and served up both the answer and the feel-good experience at the same time.

"That was the moment the solution popped into consciousness," says Kounios. "We isolated it in space and time. "

He and Beeman then traced the phenomenon back further, looking for anything that might have happened even earlier to help make that "aha" possible—and they found it. A full second before the insight, there was a burst of alpha-wave activity in the right occipital cortex, which plays a central role in processing vision. Alpha waves are known to be suppressors, dialing down brain activity rather than ramping it up. That actually makes sense in the case of problem-solving, at least when the alpha waves occur in the occipital.

Consider how people who are asked a difficult

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question will often close their eyes or look up at the ceiling or down at the floor while puzzling it out. There's a great deal of distracting visual stimuli streaming into the brain all the time, and minimizing that helps us devote more energy to an immediate task. Subjects in the study were specifically told to keep their eyes open and not look away from the words, but alpha waves could still help them process less of what they were seeing.

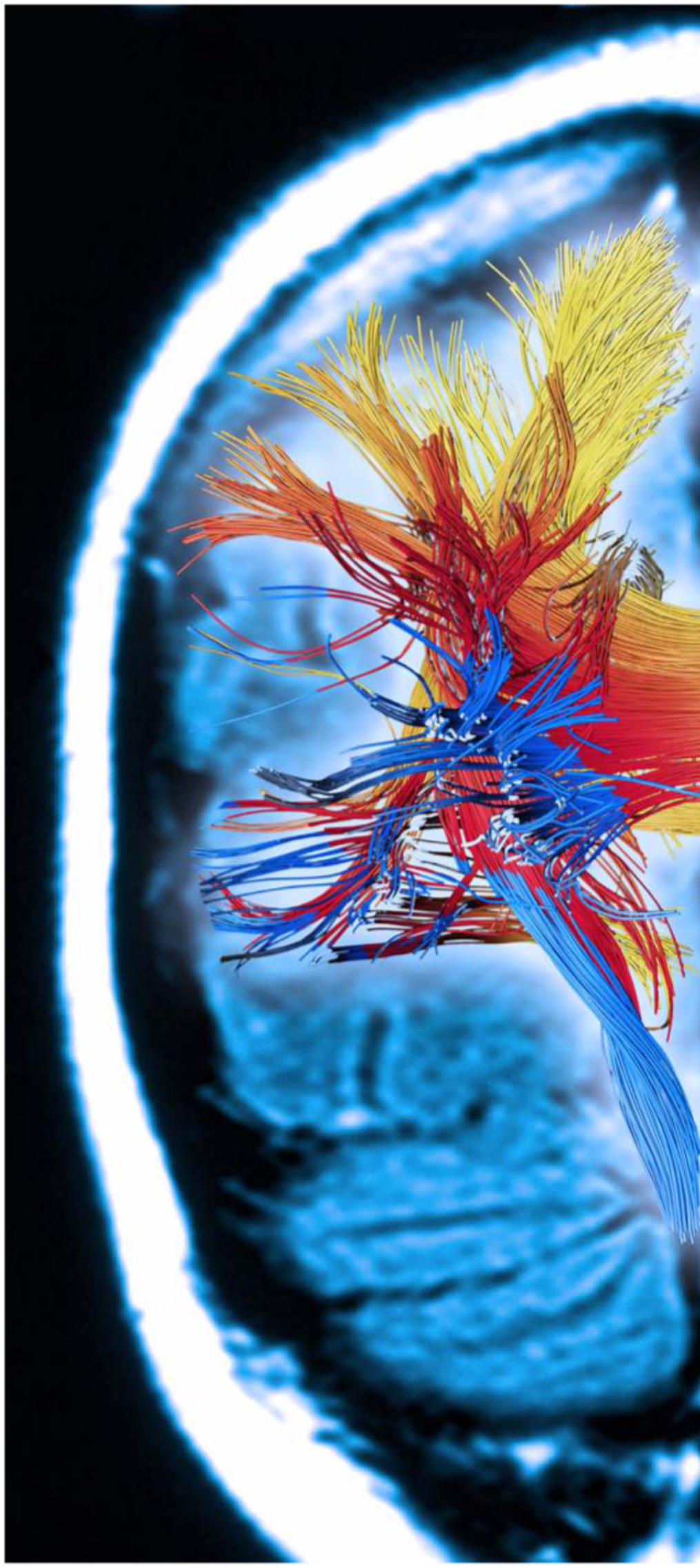
"We call it a brain blink," says Kounios. "For an instant before you have an insight, you're less aware of your environment." That, he explains, is also part of the reason so many people do their best thinking in the shower. "There's sensory restriction—white noise and you can't really see much," says Kounios.

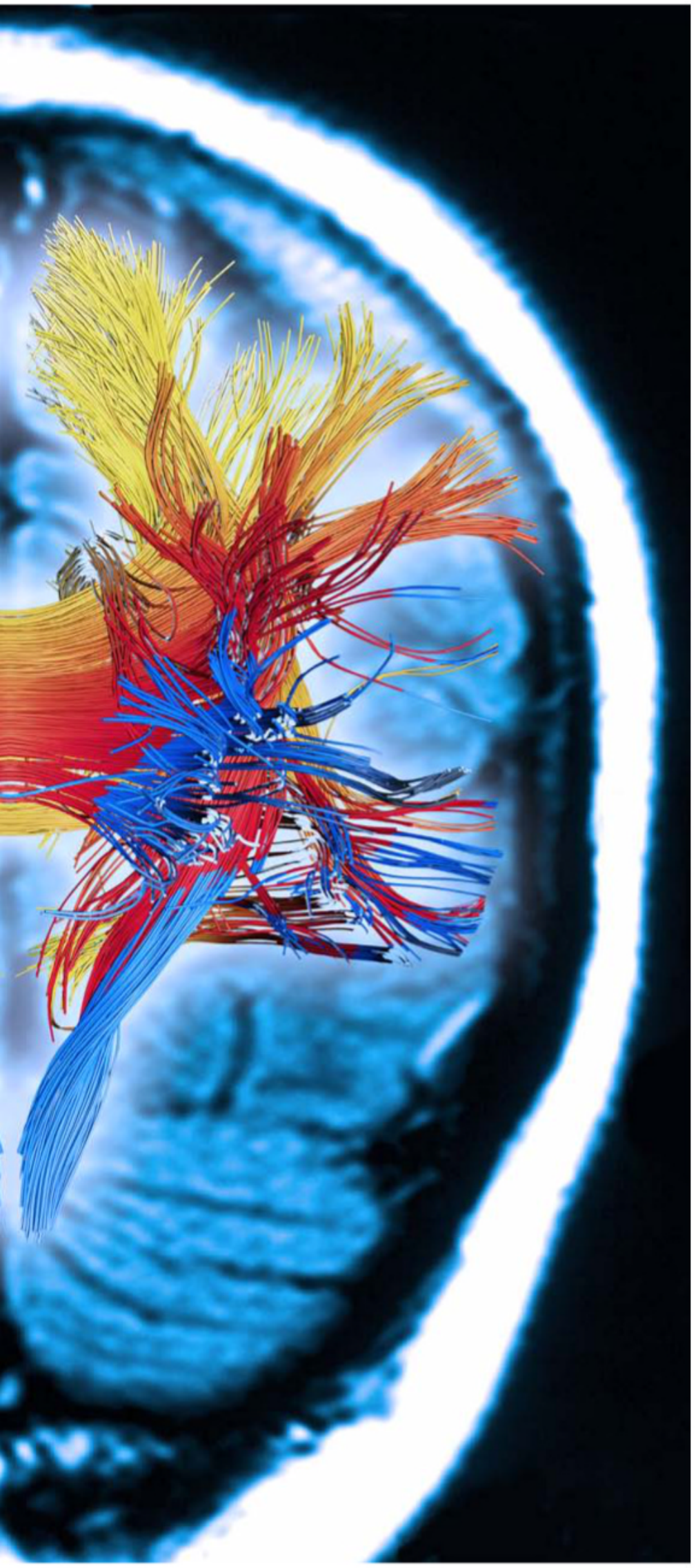
IT'S NOT JUST THE ACTIVITY OF THE BRAIN THAT DEtermines a role in creativity; it's also its wiring plan. David Dunson, a statistical scientist at Duke University, and his collaborator Rex Jung, a neuroscientist at the University of New Mexico, have been studying what are known as the brain's white-matter tracks—bundles of nerve fibers covered by fatty sheathing that serve as the cabling connecting various brain regions and structures. (The gray matter consists of the actual nerve-cell bodies and fibers within the cabling.) Dunson and Jung's work has involved both fMRI and another scanning technology, known as diffusion tensor imaging (DTI), which tracks the diffusion of water across the white matter, creating a road map of its arrangement.

"In the brain's gray matter, the diffusion of water is weak in all directions," says Dunson, "but it's directional along white-matter bundles." All he and Jung have to do is follow where that water is going.

What they've found is that white-matter roadways across the brain are nearly the same in everyone; we've all got about 1 million bundles threading there along similar routes. But there can be differences in the cables that cross from right to left.

"There aren't many connections that span the hemispheres," Dunson says. "Individuals with more of them also tended to have higher creative reasoning scores." How a greater number of cross-hemisphere connections leads to greater creativity is unknown for now, but it's not hard to imagine that bringing more processing power to any problem—especially from parts of the brain that also bring different strengths and perspectives—could certainly lead to novel solutions.





Drexel neuroscientist John Kounios (previous page) uses computer-enhanced 3-D diffusion spectral imaging (left) to scan bundles of nerve fibers that transmit signals between brain regions.

Jung stresses that what the white-matter tracks say about creativity says nothing about intelligence. Brains of people who score high on intelligence tests do have discernible features—the mass of gray matter in the higher cortex is thicker, and so is the white-matter insulation. The creative person's brain may not be similarly bulked up, which could mean, at least in theory, that it's a less intelligent brain. The key is that its regions are more closely tied together.

Many psychologists—notably Scott Barry Kaufman, author of multiple books on creativity and intelligence—take a more macro view of the creative brain, mapping three different cognitive networks that connect different brain regions and studying how they dial up or settle down as needed throughout the creative process.

The first of the three networks, known as the executive-attention network, is where the muscle work of creativity gets done. It's that network that helps us do the fiercely focused studying, reading and practicing that gives us a mastery of, say, language or music or color and light. That, in turn, is what gives us the tools we need to write poetry or compose songs or paint paintings. Executive attention requires close communication between the prefrontal cortex, which gathers and absorbs incoming information, and the posterior parietal cortex, which integrates different data streams from different sensory systems. The novice sculptor who learns new information from the color of the marble, as well as the sound it makes when it's chipped and the feel of its resistance to the hammer, is relying heavily on the posterior parietal.

Next is the imagination network, which allows the brain to do previously untried things with the information the executive-attention network has provided. Here, not only are the parietal and the prefrontal involved but also the medial temporal, which is involved in memory, and the posterior cingulate, which has a role in planning and daydreaming. When Picasso first learned the lines of the human form, he engaged his executive-attention network; when he blew all that up to develop Cubism, he was using his imagination network.

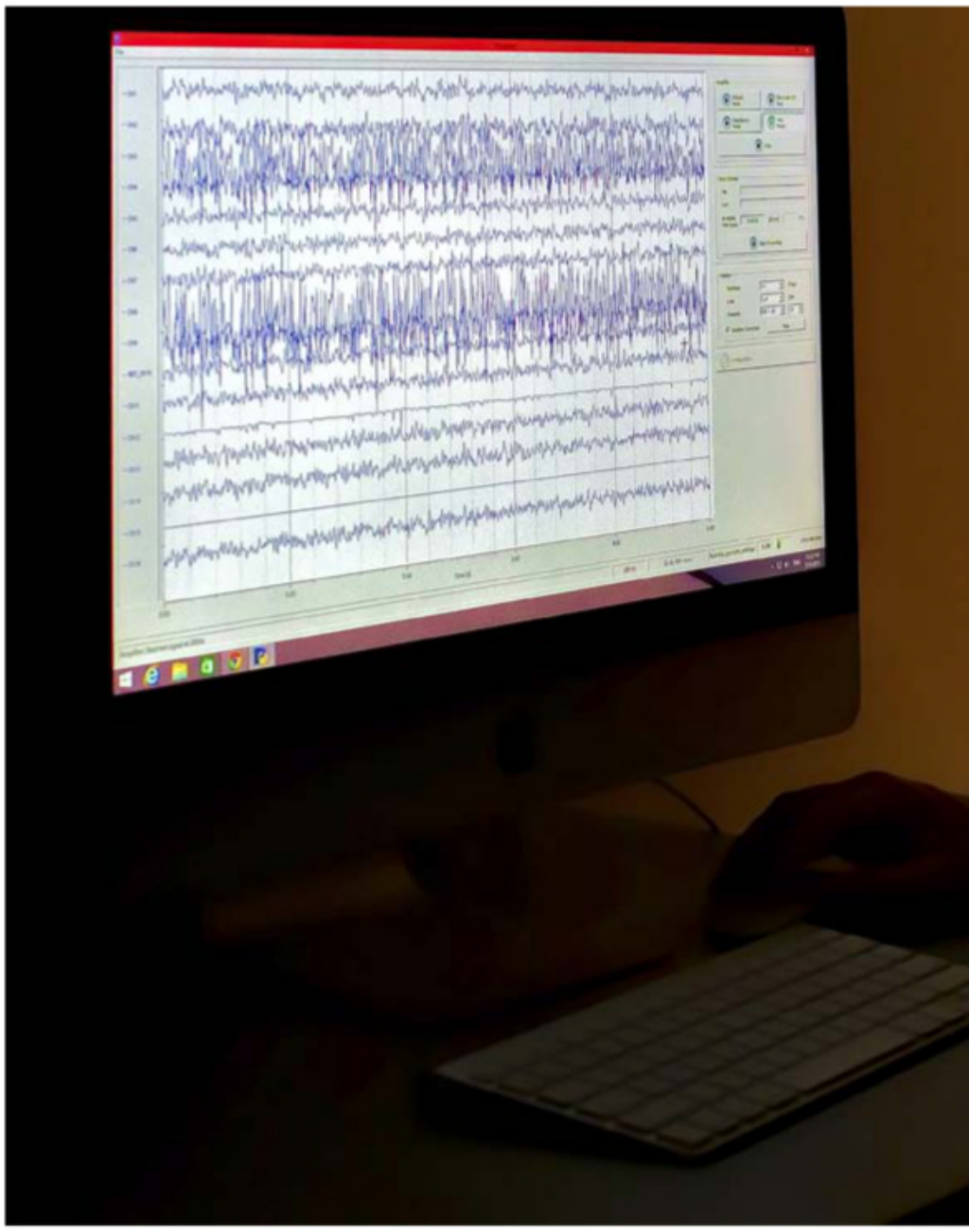
Finally, there is the salience network, which works by toggling between the anterior insula and the dorsal anterior cingulate cortex. The insula is what helps you monitor the world around you using multiple information streams, and the cingulate helps you sieve some of that out, concentrating only on what you need. The painter focuses intensely, minutely on the colors on the canvas, the condition of the brushes and the paint on the palette, but the noise of the children playing outside or the chill in the house or the smell of the dinner that's been in the oven too long are shut out.

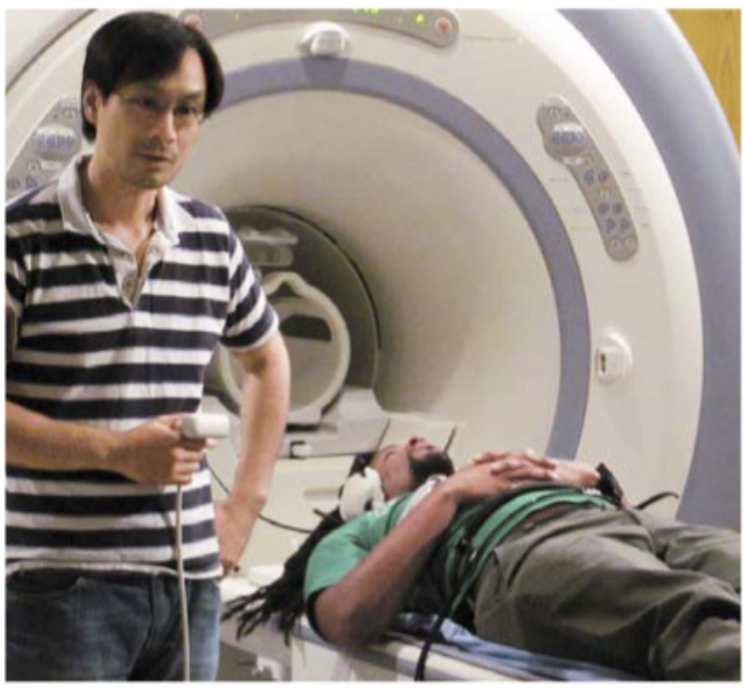
The precise balancing of all of those networks can change depending on the kind of creating that's going on. A compelling 2008 study used fMRI to monitor the brains of pianists as they either played pieces they had practiced and knew well or improvised something new. During practiced performances, the self-monitoring and self-checking functions of the prefrontal cortex remained active. During improvisation, those functions were dialed back, allowing no-fault experimentation to take place. A 2012 study found something similar in rappers who either were performing a rehearsed song or making up something as they went along. Without the prefrontal giving the rest of the imagination network room to create, jazz and freestyle rap might never exist.

"Creative people are especially good at exercising flexibility in activating or deactivating these brain networks," write Kaufman and his co-author Carolyn Gregoire in *Wired to Create*. "In doing so, they're able to juggle seemingly contradictory modes of thought—cognitive and emotional, deliberate and spontaneous."

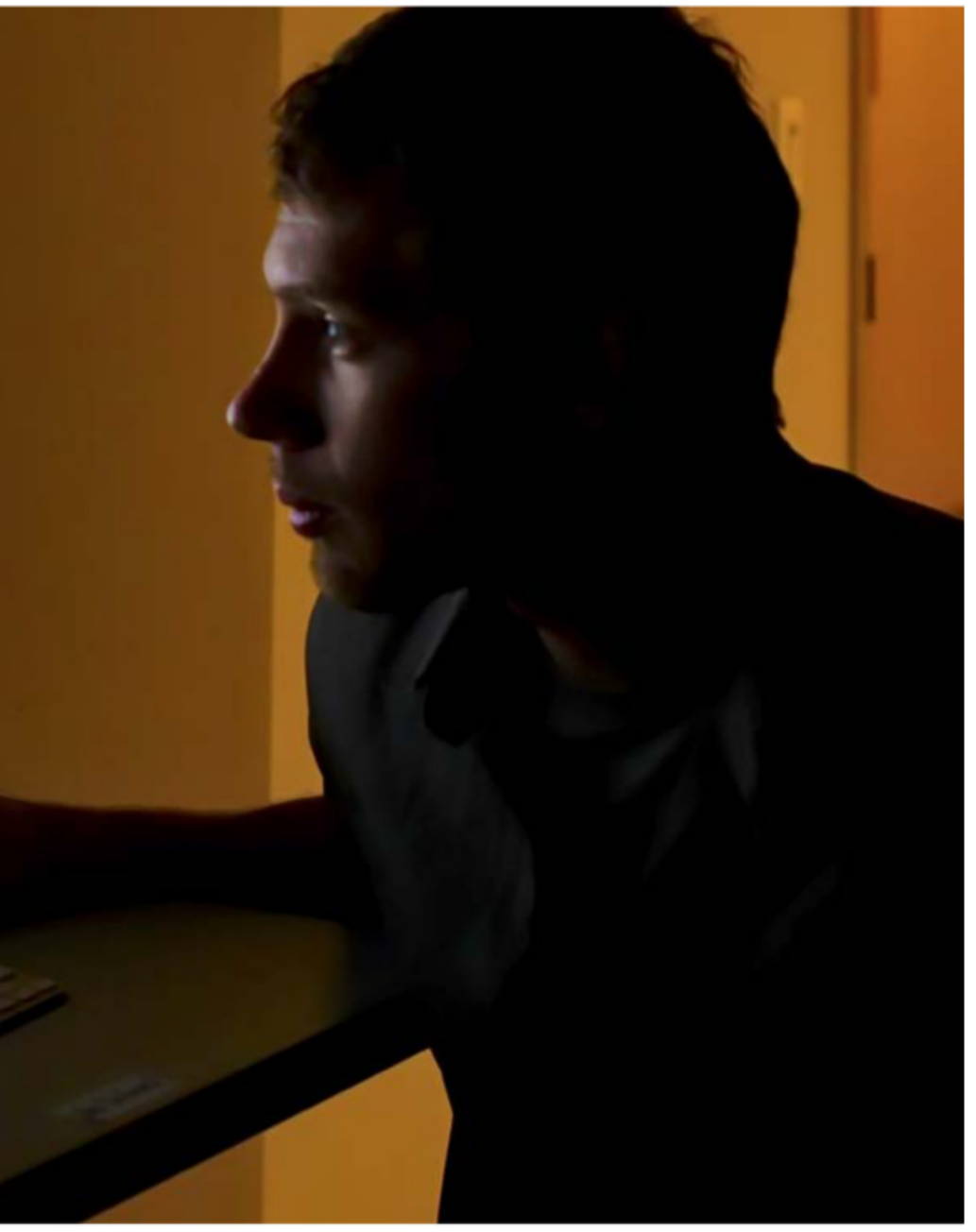
The question none of this answers is why some people are creative and others are less so, and there are clues. As in so many things, genes may play a role. Father-son authors Kingsley Amis and Martin Amis, father-daughter musicians John Raitt and Bonnie Raitt and mother-daughter actors Meryl Streep and Mamie Gummer, or Beatles and their offspring—John and Julian Lennon, Ringo Starr and Zak Starkey and George and Dhani Harrison—do suggest that there's something familial involved. But families also reward and encourage certain kinds of pursuits, so environment surely plays a role too.

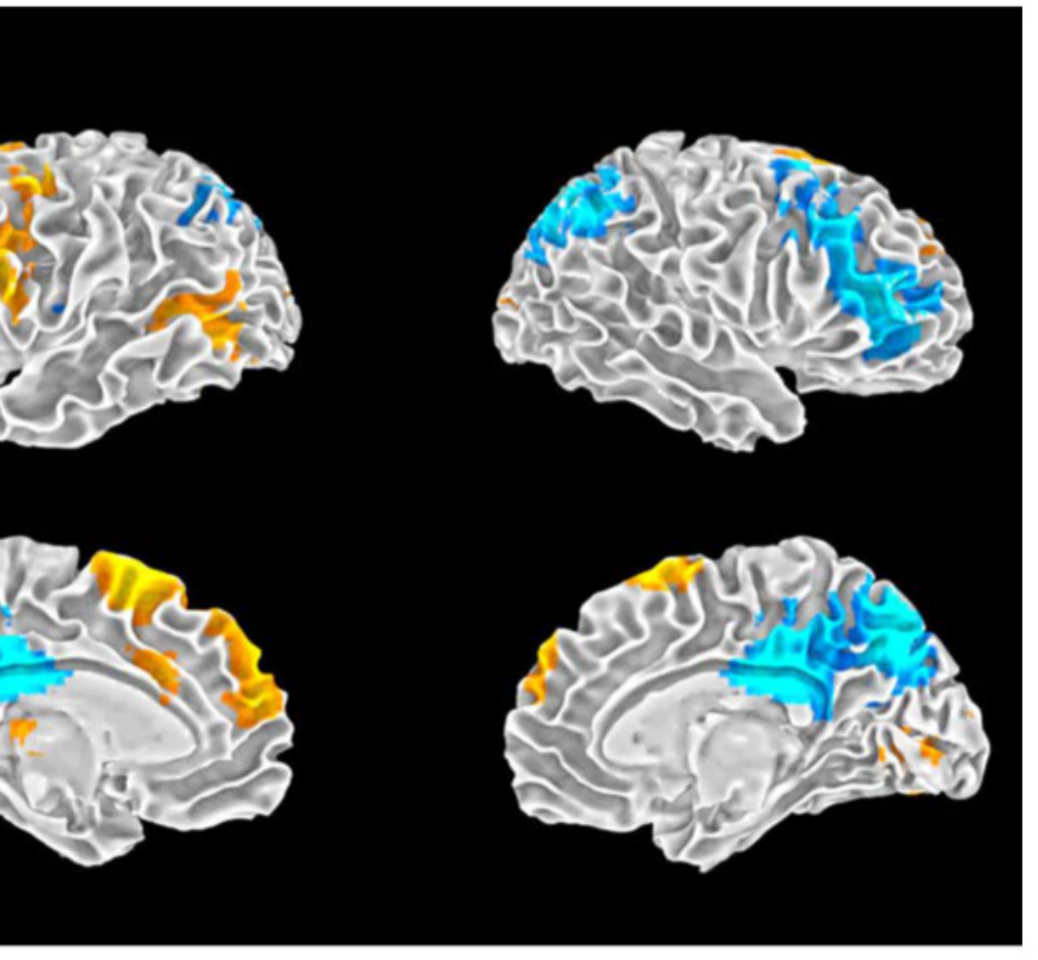
A 2013 study in *PLoS One* found a suite of genes influencing music perception, serotonin balance and cognitive and motor function, and a sample





Drexel grad student Brian Erickson (above) live-streams EEG data to detect brain signals generated in a moment of insight. Below, Drexel's Ho Ming Chow images rapper Mike Eagle's brain while Eagle performs a freestyle (orange regions are most active) and a memorized piece (highlighted in blue).





group of musicians seems to share them. And a 2016 study in *Nature Neuroscience* looked at a genetic database of nearly 83,000 people in Iceland who had tested positive for an anomaly in a particular dopamine receptor on a particular gene. Those people also had a higher-than-average risk of schizophrenia. Cross-indexing those findings with national databases of artistic societies for actors, musicians, visual artists and others, the researchers found that the people with the dopamine abnormality were overrepresented among the artists.

"It has been suggested that those less restrained by practical cognitive styles may have an advantage in artistic occupations," the authors of the study wrote. "These results provide support for the notion that creativity and psychiatric disorders, particularly schizophrenia and bipolar disorder, share psychological attributes."

A LARGER, AND RARELY EXPLORED, QUESTION IS what we mean by "creativity" in the first place. It's a label we apply to certain kinds of people and certain kinds of creations, but creativity may hide in plain sight. Beeman recalls a patient who had suffered a brain injury that affected the language centers. The patient reported being able to understand the meaning of words but missing "the complex mosaic of language." It was a term that disproved the very premise of the sentence—a creative metaphor that was part of the very mosaic that was supposedly missing.

Something similar applies to jobs that don't carry any artistic glamour. The legislator who crafts a previously elusive compromise that solves an important problem has, by any measure, created something meaningful. The teacher who shapes a personalized study program for a student who is falling behind has created a curriculum that could change a life.

"In every field you have creative and less-creative people," says Beeman. "I'd prefer to call it people who are more or less likely to have an insight."

Certainly, it's too much to say that we all create great things—and we wouldn't want it that way anyway. Greatness lies in exceptionalism—in Michelle Kwan's figure skating, in Picasso's *Guernica*, in George Gershwin's "Rhapsody in Blue."

The rest of us get to enjoy what the most accomplished creators make. And then we go on to add our own creations to a world that is only richer for them.

LEARNING FROM LEONARDO

RENAISSANCE TITAN LEONARDO DA VINCI WAS A VERY HUMAN GENIUS WHOSE WORK HOLDS LESSONS FOR US ALL (EVEN IF WE'LL NEVER PAINT A *MONA LISA*)

BY WALTER ISAACSON

YES, LEONARDO DA VINCI WAS A GENIUS: WILDLY imaginative, passionately curious and creative across multiple disciplines—painting, sculpture, architecture, anatomy, aeronautics, engineering. Yet the word "genius" oddly minimizes him by making it seem as if he were touched by lightning. His early biographer, Giorgio Vasari, a 16th-century artist, made this mistake: "Sometimes, in supernatural fashion, a single person is marvelously endowed by heaven with beauty, grace, and talent in such abundance that his every act is divine and everything he does clearly comes from God rather than from human art." In fact, the self-taught Leonardo's genius was wrought by his own will and ambition. It did not come from being the divine recipient, like Newton or Einstein, of a mind with so much processing power that we mere mortals cannot fathom it.

Part of what made Leonardo a genius, what set him apart from people who are merely extraordinarily smart, was creativity, the ability to apply imagination to intellect. His facility for combining observation with fantasy allowed him, like other creative geniuses, to make unexpected leaps that related things seen to things unseen. "Talent hits a target that no one else can hit," wrote the German philosopher Arthur Schopenhauer. "Genius hits a target no one else can see." Because they "think different," creative masterminds are sometimes considered misfits, but in the words that Steve Jobs helped craft for an Apple advertisement, "While some may see them as the crazy ones, we see genius. Because the people who are crazy enough to think they can change the world are the ones who do."

Leonardo was also a very human genius—quirky

Leonardo da Vinci, by Lattanzio Querena (1768–1853). As a young man, da Vinci was known for his handsome features and powerful physique.

and obsessive and playful and easily distracted. He made mistakes. He went off on tangents, literally, pursuing math problems that became time-sucking diversions. He left a trail of unfinished projects, among them an Adoration scene and a battle mural that were abandoned, flying machines that never flew, tanks that never rolled, a river that was never diverted and pages of brilliant treatises that piled up unpublished. "Tell me if anything was ever done," he repeatedly scribbled in notebook after notebook. "Tell me. Tell me. Tell me if ever I did a thing. . . . Tell me if anything was ever made."

His flawed humanity makes Leonardo more accessible. Even though we may never be able to match his talents, we can learn from him and try to be more like him. His life offers a wealth of lessons.

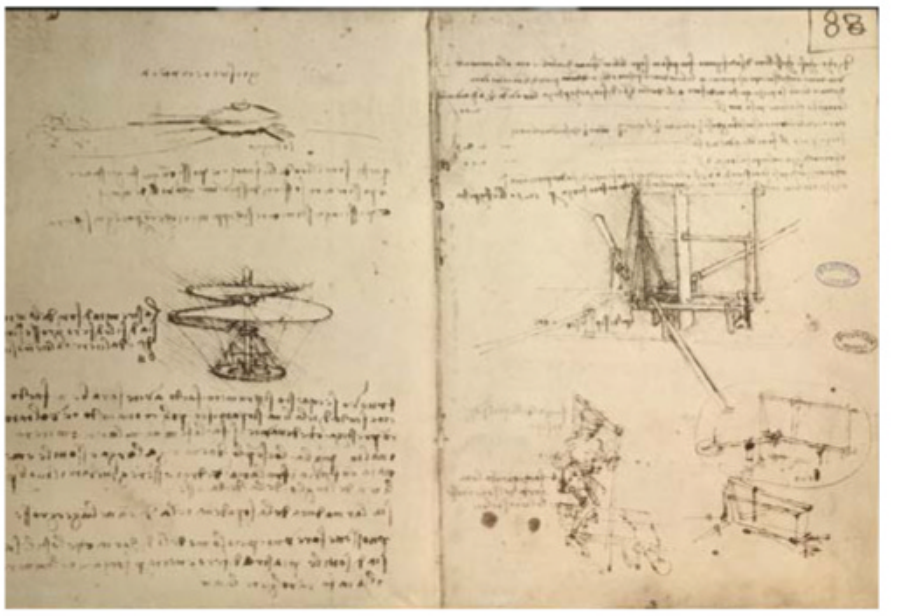
Be curious, relentlessly curious.
"I have no special talents," Einstein once wrote to a friend. "I am just passionately curious." Leonardo actually did have special talents, as did Einstein, but his distinguishing and most inspiring trait was his intense curiosity. He wanted to know what causes people to yawn, how they walk on ice in Flanders, methods for squaring a circle, what makes the aortic valve close, how light is processed in the eye and what that means for the perspective in a painting. He instructed himself to learn about the placenta of a calf, the jaw of a crocodile, the tongue of a woodpecker, the muscles of a face, the light of the moon and the edges of shadows. Being relentlessly and randomly curious about everything around us is something that each of us can push ourselves to do, every waking hour, just as he did.

Seek knowledge for its own sake.
Not all knowledge needs to be useful. Sometimes it should be pursued for pure pleasure. Leonardo did not need to know how heart valves work to paint the *Mona Lisa*, nor did he need to figure out how fossils got to the top of mountains to produce *Virgin of the Rocks*. By allowing himself to be driven by pure curiosity, he got to explore more horizons and see more connections than anyone else of his era.

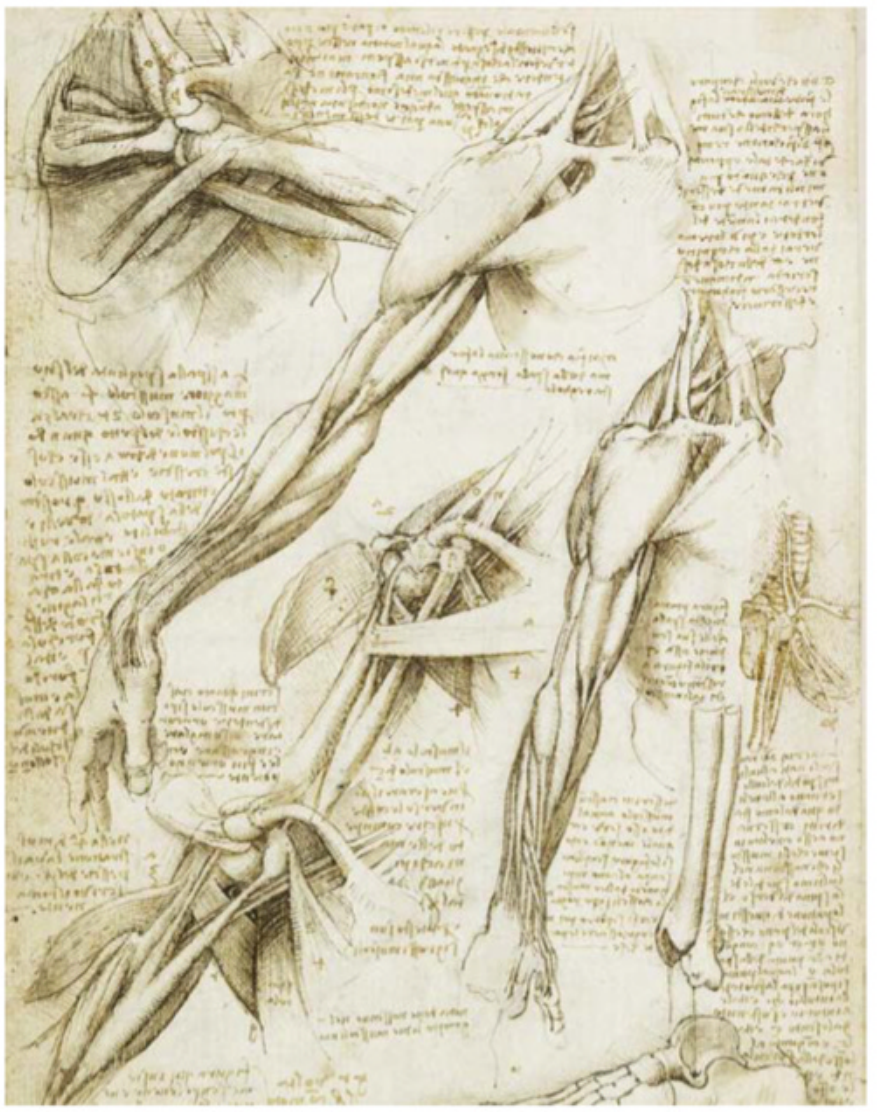
Retain a childlike sense of wonder.
At a certain point in life, most of us quit puzzling over everyday phenomena. We might savor the beauty of a blue sky, but we no longer bother to wonder why it is that color. Leonardo did. So did

Da Vinci's Notebook

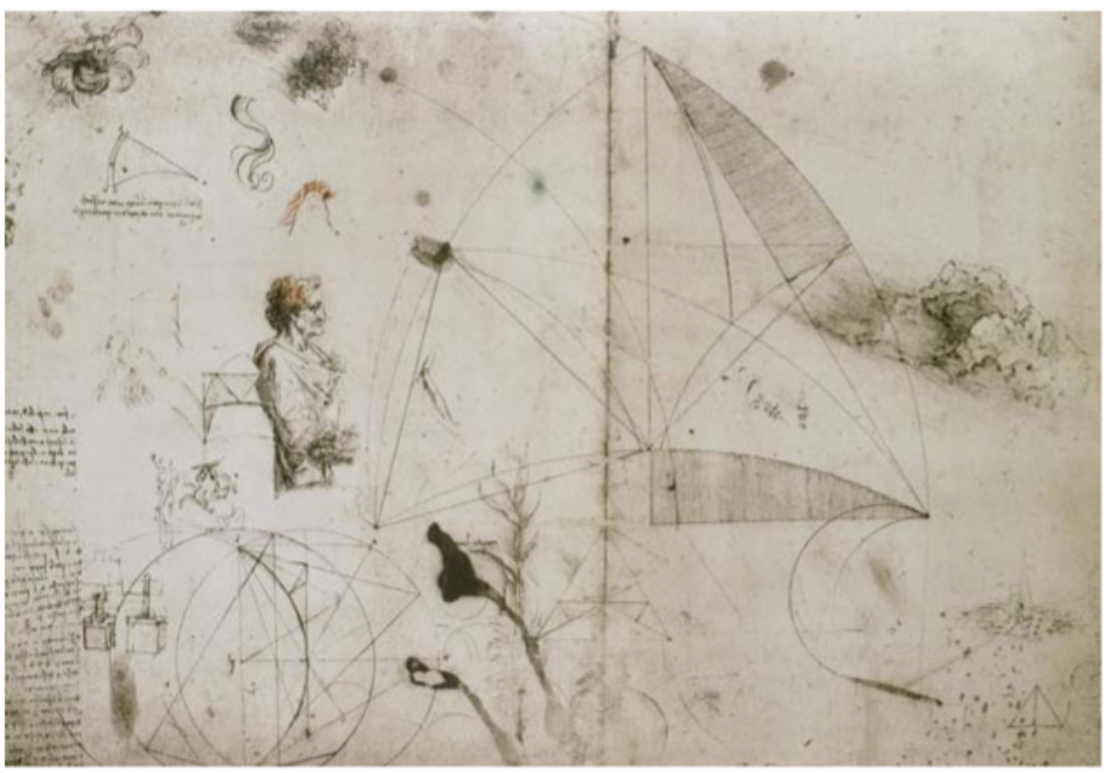
Written backward (his reasons remain unclear) and vividly illustrated, it reveals a restless, insatiably curious mind with an almost limitless range available.



Above, Leonardo's rendition of a flying machine; below, anatomical drawings of the shoulder, arms and foot

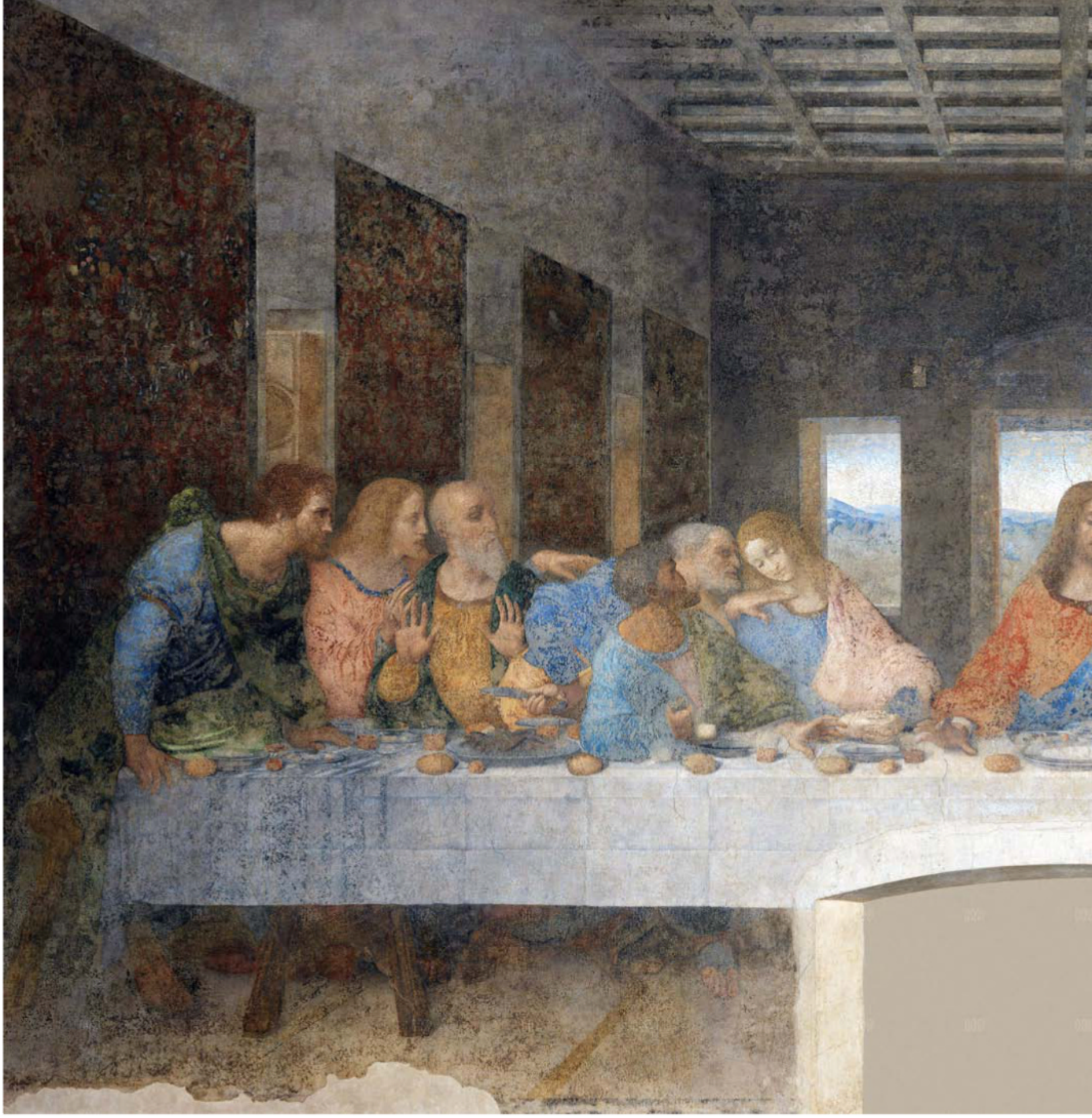


Leonardo sketched the turbulence of a waterfall flowing into a still pool and, below, depicted an elderly man along with some geometrical diagrams.



This detail of a flying machine shows a wing mechanism, which is being manipulated by a human pilot (sprawled out in the prone position).

The quintessential Renaissance man was given to flights of fancy and fantasy, as evidenced in this drawing of a fight between horses and a dragon.



Einstein, who wrote to another friend, "You and I never cease to stand like curious children before the great mystery into which we were born." We should be careful to never outgrow our wonder years or to let our children do so.

Observe.

Leonardo's greatest skill was his acute ability to observe things. It was the talent that empowered his curiosity, and vice versa. It was not a magical gift but a product of effort. When he visited the moats surrounding Sforza Castle, he looked at the four-winged dragonflies and noticed how the wing pairs alternate in motion. When he walked around town, he observed how the facial expressions of people relate to their emotions, and he discerned how light bounces off different surfaces. He saw which birds move their wings faster on the upswing than on the downswing, and which do the opposite. This, too, we can emulate. Water flowing into a bowl? Look, as he did, at exactly how the eddies swirl. Then wonder why.

Start with the details.

In his notebook, Leonardo shared a trick for observing something carefully: Do it in steps, starting with each detail. A page of a book, he noted, cannot be

The Last Supper ***(also below in a preliminary sketch) was painted in Milan for Leonardo's patron Duke Ludovico Sforza.***

absorbed in one stare; you need to go word by word. "If you wish to have a sound knowledge of the forms of objects, begin with the details of them, and do not go on to the second step until you have the first well fixed in memory."

See things unseen.

Leonardo's primary activity in many of his formative years was conjuring up pageants, performances and plays. He mixed theatrical ingenuity with fantasy. This gave him a combinatory creativity. He could see birds in flight and also angels, lions roaring and also dragons.

Go down rabbit holes.
Leonardo filled the opening pages of one of his notebooks with 169 attempts to square a circle. In eight pages of his *Codex Leicester*, he recorded 730 findings about the flow of water; in another notebook, he listed 67 words that describe different types of moving water. He measured every segment of the human body, calculated their proportional relationships, and then did the same for a horse. He drilled down for the pure joy of geeking out.

Get distracted.
The greatest rap on Leonardo was that he'd become scattered—say, doing scientific experiments instead of painting *The Adoration of the Magi*. But every passion he had deepened his appreciation for the patterns of nature. Leonardo teaches us the value of being focused on things that fascinate us but also, at times, being distracted and pursuing some shiny new idea you happen to stumble upon.

Respect facts.
Leonardo was a forerunner of the age of observational experiments and critical thinking. When he came up with an idea, he devised an experiment to test it. And when his experience showed that a theory was flawed—such as his belief that the springs within the earth are replenished the same way as blood vessels in humans—he abandoned his theory and sought a new one. This practice became common a century later, during the age of Galileo and Bacon. It has, however, become a bit less prevalent in this era of "alternative facts." If we want to be more like Leonardo, we have to be fearless about changing our minds based on new—and real—information.

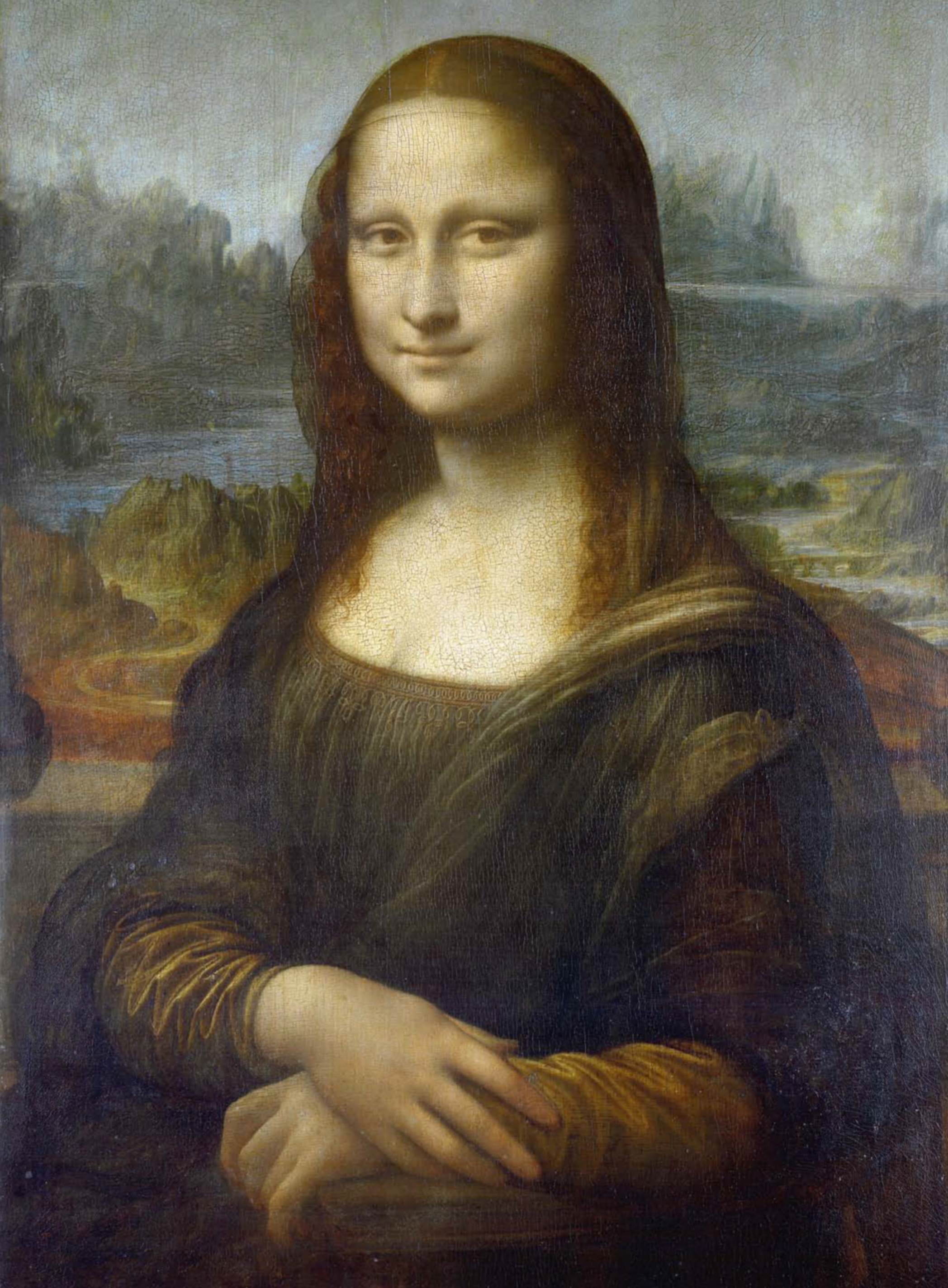
Procrastinate.
While painting *The Last Supper*, Leonardo would sometimes stare at the work for an hour, finally make one small stroke, and then leave. He told Duke Ludovico creativity requires time for ideas to marinate and intuitions to gel. "Men of lofty genius sometimes accomplish the most when they work least," he explained, "for their minds are occupied with their ideas and the perfection of their conceptions, to which they afterwards give form." Most of us don't need advice to procrastinate; we do it naturally. But procrastinating like Leonardo requires work: it involves gathering all possible facts and ideas, and only then allowing the collection to simmer.

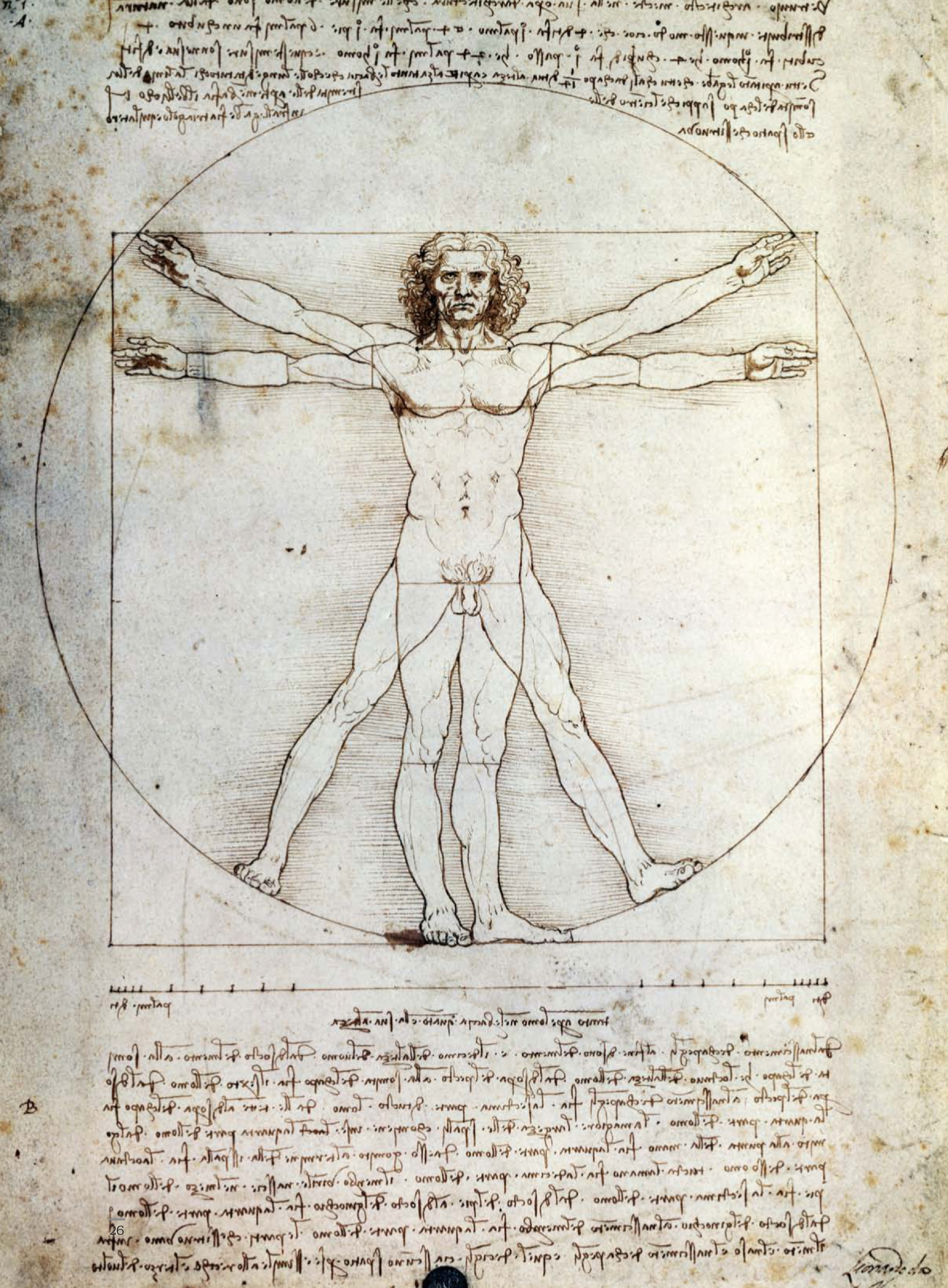
Let the perfect be the enemy of the good.
When Leonardo could not make the perspective in *The Battle of Anghiari* or the interaction in *The Adoration of the Magi* work perfectly, he abandoned them rather than produce a work that was merely good enough. He carried around masterpieces such as his *Saint Anne* and the *Mona Lisa* to the end, knowing there would always be a new stroke he could add. Likewise, Steve Jobs was such a perfectionist that he held up shipping the original Macintosh until his team could make the circuit boards inside look beautiful, even though no one would ever see them. Both he and Leonardo knew that real artists care about the beauty even of the parts unseen. Eventually, Jobs embraced a countermaxim, "Real artists ship," which means that sometimes you ought to deliver a product even when there are still improvements that could be made. That is a good rule for daily life. But there are times when it's nice to be like Leonardo and not let go of something until it's perfect.

Think visually.
Leonardo was not blessed with the ability to formulate math equations or abstractions. So he had to visualize them, which he did with his studies of proportions, his rules of perspective, his method for calculating reflections from concave mirrors and his ways of changing one shape into another of the same size. Too often, when we learn a formula or a rule—even one so simple as the method for multiplying numbers or mixing a paint color—we no longer visualize how it works. As a result, we lose our appreciation for the underlying beauty of nature's laws.

Avoid silos.
At the end of many of his product presentations, Steve Jobs displayed a slide of a sign that showed the intersection of "Liberal Arts" and "Technology" streets. He knew that at such crossroads lie creativity. Leonardo had a free-range mind that merrily wandered across all the disciplines of the arts, sciences, engineering and humanities. His knowledge of how light strikes the retina helped inform the perspective in *The Last Supper*, and on a page of anatomical drawings depicting the dissection of lips, he drew the smile that would reappear in the *Mona Lisa*.

Lisa Gherardini (1479–1542), a merchant's wife, likely posed for the world's most famous painting.





In Vitruvian Man *(1490), Leonardo blended anatomy with geometry to show ideal human proportions.*

He knew that art was a science and that science was an art. Whether he was drawing a fetus in the womb or the swirls of a deluge, he blurred the distinction between the two.

Let your reach exceed your grasp.
Imagine, as he did, how you would build a human-powered flying machine or divert a river. Even try to devise a perpetual-motion machine or square a circle using only a ruler and a compass. There are some problems we will never solve. Learn why.

Indulge fantasy.
Leonardo's fantasies pervaded everything he touched: his theatrical productions, plans to divert rivers, designs for ideal cities, schemes for flying machines, and almost every aspect of his art as well as engineering. At first glance his susceptibility to fantasia might seem to be a failing, one that reveals a lack of discipline and diligence that was related to his propensity to abandon artworks and treatises unfinished. To some extent, that is true. Vision without execution is hallucination. But Leonardo's ability to blur the line between reality and fantasy—just like his sfumato techniques for blurring the lines of a painting—was actually a key to his creativity. Skill without imagination is barren. Leonardo knew how to marry observation and imagination, which made him history's consummate innovator.

Create for yourself, not just for patrons.
No matter how hard the rich and powerful marchesa Isabella d'Este begged, Leonardo would not paint her portrait. But he did begin one of a silk merchant's wife named Lisa. He did it because he wanted to, and he kept working on it for the rest of his life, never delivering it to the silk merchant.

Collaborate.
Genius is often considered the purview of loners who retreat to their garrets and are struck by creative lightning. Like many myths, that of the lone genius has some truth to it. But there's usually more to the story. The Madonnas and drapery studies produced in Verrocchio's studio, and the versions of *Virgin of the Rocks* and *Madonna of the Yarnwinder* and other paintings from Leonardo's studio, were created in such a collaborative manner that it is hard to tell whose hand made which strokes. *Vitruvian Man* was produced after Leonardo shared ideas and sketches with friends. His best anatomy studies came when he was working in partnership with Marcantonio della Torre. And his most fun work came from collaborations on theatrical productions and evening entertainments at the Sforza court. Genius starts with individual brilliance. It requires singular vision. But executing it often entails working with others. Innovation is a team sport. Creativity is a collaborative endeavor.

Make lists.
And be sure to put odd things on them. Leonardo's to-do lists may have been the greatest testaments to pure curiosity the world has ever seen.

Take notes, on paper.
Five hundred years later, Leonardo's notebooks are around to astonish and inspire us. Fifty years from now, our own notebooks, if we work up the initiative to start writing them, will be around to astonish and inspire our grandchildren, unlike our tweets and Facebook posts.

Be open to mystery.
Not everything needs sharp lines. The 15th century of Leonardo and Columbus and Gutenberg was a time of invention, exploration and the spread of knowledge by new technologies. In short, it was a time like our own. That is why we have much to learn from Leonardo. His ability to combine art, science, technology, the humanities and imagination remains an enduring recipe for creativity. So, too, is the ease with which he was a bit of a misfit: illegitimate, gay, vegetarian, left-handed, easily distracted and at times heretical. Florence flourished in the 15th century because it was comfortable with such people. Above all, Leonardo's relentless curiosity and experimentation should remind us of the importance of instilling, in both ourselves and our children, not just received knowledge but also a willingness to question it—to be imaginative and, like talented misfits and rebels in any era, to think different.

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UNDER THE HOOD OF CREATIVITY

HOW THE BRAIN BENDS, BREAKS AND BLENDS EXISTING CONCEPTS AND OBJECTS TO INVENT BOLD NEW FORMS

BY ANTHONY BRANDT AND DAVID EAGLEMAN

Apollo 13's mission control engineers (left) and artist Pablo Picasso both broke the mold, reconfiguring traditional forms in new ways.

SEVERAL HUNDRED PEOPLE SCRAMBLE IN A CONtrol room in Houston, trying to save three humans ensnared in outer space. It's 1970, and Apollo 13 is two days into its moonshot when its oxygen tank explodes, spewing debris into space and crippling the craft. Fuel, water, electricity and air are running out. The only working part of the craft is the lunar module. NASA has simulated many possible breakdowns, but not this one.

A day and a half into the crisis, carbon dioxide reaches dangerous levels in the astronauts' tight quarters. The lunar module has a filtration system, but all of its cylindrical air scrubbers have been exhausted. The only remaining option is to salvage unused canisters from the abandoned command module—but those are square. How to fit a square scrubber into a round hole?

Working from an inventory of what's on board, engineers at Mission Control devise an adaptor cobbled together from a plastic bag, a sock, pieces of cardboard and a hose from a pressure suit, all held together by duct tape. They tell the crew to tear off the plastic cover from the flight plan folder, and to use it as a funnel to guide air into the scrubber. They have the astronauts pull out the plastic-wrapped thermal undergarments that were originally meant to be worn under spacesuits while bouncing on the moon. Piece by piece, the astronauts assemble the makeshift filter and install it.

To everyone's relief, carbon dioxide levels return to normal. But other problems quickly follow. As Apollo 13 draws closer to re-entry, power is growing short in the command module. When the spacecraft was designed, it had never crossed anyone's mind that the command module batteries might have to be charged from the lunar module—it was supposed

to be the other way around. Faced with a problem they hadn't foreseen, the engineers improvise an entirely new protocol.

In the pre-dawn hours of April 17, 1970—80 hours into the crisis—the astronauts prepare for their final descent. A minute and a half later, word reaches the control room: Apollo 13 is safe.

Now travel back 63 years earlier, to 1907. In a small studio in Paris, a young painter named Pablo Picasso sets up his easel. He sets to work on a provocative project: a portrait of prostitutes in a brothel. An unvarnished look at sexual vice.

Picasso begins with charcoal sketches of heads, bodies, fruit. In his first versions, a sailor and male medical student are part of the scene. He decides to remove the men, settling on the five women as his subjects. After hundreds of sketches, he sets to work on the full canvas. At one point, he invites his mistress and several friends to see the work in progress; their reaction so disappoints him that he sets aside the painting. But months later he returns to it, working in secret. Picasso views the portrait of the prostitutes as an "exorcism" from his previous way of painting: the more time he spends on it, the further he moves from his earlier work. When he invites people back to see it again, their reaction is even more hostile. Dismayed, Picasso rolls up the canvas and puts it in his closet. He waits nine years to show it in public. Critic John Richardson would later call that painting—*Les Demoiselles d'Avignon*—the most original painting in 700 years.

What made Picasso's painting so original? He changed the goal that European painters had subscribed to for centuries: the pretense of being true to life. In Picasso's hands, limbs appear twisted, two of the women have mask-like faces, and the five figures seem to have been painted in five different styles. Here, ordinary people no longer look entirely human. Picasso's painting undercut Western notions of beauty, decorum and verisimilitude all at once. *Les Demoiselles* came to represent one of the fiercest blows ever delivered to artistic tradition.

And what does this have in common with the story of Apollo 13? At first glance, not much. Saving the Apollo 13 was collaborative. Picasso worked alone. The NASA engineers raced against the clock. Picasso took months to commit his ideas to canvas, and nearly a decade to show his art. The engineers weren't seeking points for originality: their goal was a functional solution. "Functional" was the last thing

Picasso's revolutionary* Les Demoiselles d'Avignon *(1907) reshaped the female body—and so did modern dancer Martha Graham (shown in 1940).

on Picasso's mind—his goal was to produce something unprecedented.

Yet the cognitive routines underlying NASA's and Picasso's creative acts are the same. And this is not just true of engineers and artists—it's true of hair stylists, accountants, architects, farmers, lepidopterists or any other human who creates something previously unseen. When they break the mold of the standard to generate novelty, it is the result of basic software running in the brain. The human brain doesn't passively take in experience like a recorder; instead, it constantly works over the sensory data it receives—and the fruit of that mental labor is new versions of the world. The basic cognitive software of brains—which drinks in the milieu and procreates new versions – gives rise to everything that surrounds us.

We propose a framework that divides the cogni-

tive landscape into three basic strategies: bending, breaking and blending. These, we suggest, are the primary means by which all ideas evolve.

BENDING

In bending, an original is modified or twisted out of shape. For instance, size can bend. French artist Anastassia Elias creates miniature art that fits inside toilet-paper rolls.

What might this art piece have to do with, say, making nighttime driving safer? At first glance, not much. But the same cognitive processes were at work when a baffling problem about windshields was solved. Early in the automobile age, riding around after dark was dangerous because of the blinding glare caused by approaching headlights. American inventor Edwin Land was determined to create windshields that were glare-resistant. To increase visibility, he turned to the idea of polarization. It wasn't a new concept: during the reign of Napoleon, a French engineer had noticed that the sunny reflections of palace windows were less brilliant if he looked at them through a calcite crystal. Several generations of inventors, however, had struggled to put large crystals to practical use. Imagine a windshield made up of six-inch-thick crystals: you wouldn't be able to see through it. Like everyone before him, Land tried working with large crystals but got nowhere. Then one day he had his "aha" moment: shrink the crystals. What Land later described as his "orthogonal thinking" involved the same mental process as Elias' diminutive artwork. Turning the crystals from something you held in your hand to something you couldn't see, he soon succeeded in making sheets of glass with thousands of tiny crystals embedded inside them. Because the crystals were so microscopically small, the glass was both transparent

The human brain doesn't passively take in experience like a recorder; instead, it constantly works over the sensory data.

and able to cut down on the glare. The driver got a better view of the road, even while the creativity that produced it remained invisible.

Like size, shape can bend. In classical Western ballet, dancers' postures create straight lines as much as possible. Starting in the 1920s, dancer and choreographer Martha Graham used innovative poses, movements and fabric to bend the human form. As dancers can change shape, so can structures. Using computer modeling and new building materials, architect Frank Gehry warps the normally flat planes of building exteriors into rippling and twisting facades.

How might bending allow the cars of the future to hold more fuel? One of the impediments to converting engines from gasoline to hydrogen is the bulkiness of the tank: standard hydrogen tanks are barrel-shaped and take up too much cargo space. A company called Volute has developed a conforming tank that folds upon itself in layers and can snake into unused space in the car body, finding ways to make the volume work by bending and twisting it.

By reworking something that already exists, bending opens up a wellspring of possibilities through alterations in size, shape, material, and more. As a result of our perpetual neural manipulations, human culture incorporates an ever-expanding series of variations on themes passed down from generation to generation.

BREAKING

In breaking, something whole is taken apart, and something new assembled out of the fragments.

Artists Georges Braque and Pablo Picasso broke apart the visual plane into a jigsaw puzzle of angles and perspectives in Cubism. In his massive painting *Guernica*, Picasso used breaking to illustrate the horrors of war. Bits and pieces of civilians, animals and soldiers—a torso, a leg, a head, all disjointed with no figure complete—create a stark representation of brutality and suffering.

Similarly, breaking up a continuous area revolutionized mobile communication. The first mobile phone systems worked just like television and radio broadcasting: in a given area, there was a single tower transmitting widely in all directions. Reception was great. But while it didn't matter how many people were watching TV at the same time, it did matter how many people were making calls: only a few dozen could do so simultaneously. Any more than that and the system was overloaded. Dialing at

“People ask me if I’m an artist or an architect,” Frank Gehry said. “But I think they’re the same.” A few of his dynamically contorted creations, clockwise from left: the Dancing House in Prague (collaboration with Vlado Milunic); the Cleveland Clinic’s Lou Ruvo Center for Brain Health in Las Vegas; the Guggenheim Museum in Bilbao, Spain

From left: Picasso's Guernica *(1937) and Bruno Catalano's sculpture* The Travelers *(2013) break up the body into fragments; the Sphinx at Giza in Cairo (c. 2500 B.C.) blends human and lion traits.*

a busy time of day, you were apt to get a busy signal. Engineers at Bell Labs recognized that treating mobile calls like TV wasn't working. They took an innovative tack: they divided a single coverage area into small "cells," each of which had its own tower. The modern cellphone was born.

The great advantage of this system was that it enabled the same broadcast frequency to be reused in different neighborhoods, so more people could be on their phones at the same time. In a Cubist painting, the partitioning of a continuous area is on view. With cellphones, the idea runs in the background. All we know is that the call didn't drop.

Breaking also gives the option of leaving pieces out. Bruno Catalano leaves out whole chunks of the human body in his sculpture *The Travelers*.

This technique of breaking down and discarding parts has created new ways to study the brain. Neuroscientists looking at brain tissue have long been stymied by the fact that the brain contains detailed circuits—but those are buried deep within the brain and are impossible to see. Scientists typically solve that problem by cutting the brain into very thin slices—a form of breaking—and creating an image of each slice before painstakingly reassembling the entire brain in a digital simulation. However, because so many neural connections are damaged in the slicing process, the computer model is at best an approximation.

Neuroscientists Karl Deisseroth and Kwanghun Chung and their team found an alternate solution. Fatty molecules called lipids help hold the brain together, but they also diffuse light. The researchers devised a way to flush the lipids out of a dead mouse's brain while keeping the brain's structure intact. With the lipids gone, the mouse's gray matter becomes transparent. Dubbed the CLARITY method, it removes part of the original but does not fill in the gaps—in this case, gaps that enable neuroscientists to study large populations of neurons in a way never before possible.

Breaking enables us to take something solid or continuous and fracture it into manageable pieces. Our brains parse the world into units that can then be rebuilt and reshaped.

BLENDING

In blending, the brain combines two or more sources in novel ways. All over the world, representations of humans and animals have blended to create mythical creatures. In ancient Greece, a man and a bull were combined to create a Minotaur. For the Egyptians, human plus lion equaled the Sphinx. In Africa, merging a woman and a fish produced a *mami wata*—a mermaid. What magic happened under the hood to generate these chimeras? A new merger of familiar concepts.

As in myth, so in science. Genetics professor Randy Lewis knew that spider silk had great commercial potential: it is many times stronger than

steel. If only the silk could be produced in bulk, one could weave apparel such as ultra-light bulletproof vests. But it is difficult to farm spiders—when confined in large numbers, they turn into cannibals and eat one another. On top of that, harvesting silk from spiders is arduous: it took 82 people working with 1 million spiders several years to extract enough silk to weave 44 square feet of cloth. So Lewis came up with an innovative idea: splice the DNA responsible for silk manufacturing into a goat. The result: Freckles the spider-goat. Freckles looks like a goat but she secretes spider silk in her milk. Lewis and his team milk her and then extract the strands of spider silk in the lab.

Genetic engineering has opened up the frontier of real-life chimeras, producing not only spider-goats but also bacteria that make human insulin, fish and pigs that glow with the genes of jellyfish, and Ruppy the Puppy, the world's first transgenic dog, who turns a fluorescent red under ultraviolet light thanks to a gene from a sea anemone.

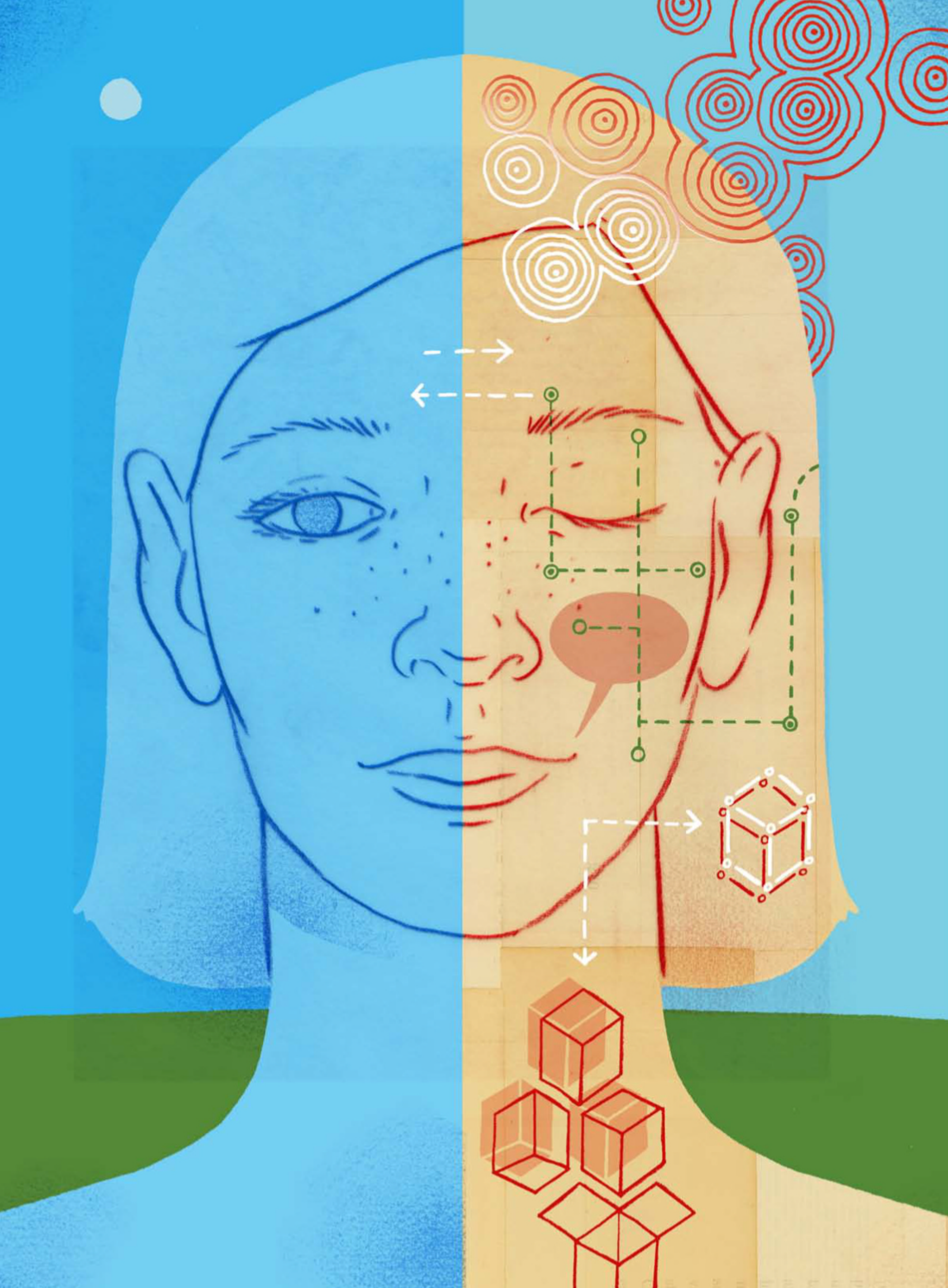
By enabling different lines of thought to breed in novel ways, blending is a powerful engine of innovation. The human mind represents an enormous jungle of memories and sensations in which the mating of ideas is unconstrained.

Blending combines two or more sources in novel ways to create something completely different.

WHEN NASA ENGINEERS REVERSED THE ELECTRIC current aboard Apollo 13 to recharge the command module batteries, they were bending; so too was Picasso when he warped human bodies in *Les Demoiselles d'Avignon*. When the engineers tore apart equipment, they were breaking; so too was Picasso when he fractured the visual plane. When the engineers taped together cardboard, plastic, a sock and a hose to build an air filter, they were blending; so too was Picasso when he incorporated Iberian and African masks into his portrait. The engineers' and artist's materials were different, but they innovated by the same means: bending, breaking and blending what they knew. As a result they each made history, one with a daring rescue, the other with groundbreaking art.

Bending, breaking and blending are tools our brains use to turn experience into novel output; they are the basic routines in the software of invention. The raw materials are provided from every aspect of our involvement in the world: turns of phrase, musical riffs, toys, photos, eye-opening concepts and every memory we've ever accumulated. By intertwining these cognitive tools, human minds ply, split and merge their experiences into new forms. Our civilization blossoms from these zigzagging branches of derivations, reassemblies and recombinations.

Adapted with permission from The Runaway Species *by Anthony Brandt and David Eagleman, Catapult (2017).*



CHAPTER TWO

THE CREATIVE MIND

INSIDE THE BIOLOGICAL, INTELLECTUAL AND EMOTIONAL FORCES THAT FUEL CREATIVITY

"I tend to gather strong visual inspiration while having verbal experiences—reading an interesting article or well-written phrase, glimpsing a clever book title or overhearing a random pairing of words. Mental pictures appear!"

—Leigh Wells

Wells has been creating images and lettering for advertising, design, publishing and editorial clients in the U.S. and internationally for more than 20 years. Her work has appeared in major publications such as *Harper's*, the *New York Times* and TIME, including this special edition (left).

ARE NEUROTICS MORE CREATIVE?

THEY DAYDREAM AND RUMINATE, DWELLING ON HYPOTHETICALS AND WORST-CASE-SCENARIOS. SOME RESEARCHERS BELIEVE THAT CAN BE A GOOD THING

BY DAVID BERREBY

IF YOU'D WANTED TO MEET CHARLES DARWIN AFTER he published *On the Origin of Species* in 1859, you would not have found him basking in satisfaction over a job well done. In fact, you probably would not have found him at all. Stressed by social life, he'd had a mirror installed so he could see people approaching in time to hide from them. Darwin just wasn't a sunny man. On an ordinary day a couple of years after his book had appeared—and revolutionized humanity's understanding of the world—he wrote a friend: "I am very poorly today & very stupid & hate everybody & everything. One lives only to make blunders."

What's a person to do with those sorts of troubling thoughts and sad moods? Almost all creative people have them—ugly little voices inside your head that tell you you're very stupid and hate everybody, and you forgot to buy cat food, and your back hurts. Which, by the way, could be a slipped disc or worse—who knows? Remember your friend's cousin who went into the hospital for supposedly routine surgery and never came out?

The most common answer, of course, is this: Find a way to turn those voices off, or at least tamp them down. If you're the sort of person who tends to experience negative thoughts and feelings—in other words, if you're the textbook definition of neurotic—you've almost certainly been told that creativity and neurosis are opposites.

"My feeling is that an enormous amount of what we think of as neurosis is actually blocked creativity," Julia Cameron, whose best-selling *The Artist's Way* has instructed millions of people to liberate themselves from their neuroses, once told an interviewer. "When people begin living in their creativity, the 'neurosis' disappears."

Psychologist Adam M. Perkins of King's College London thinks that's all wrong. "Neuroticism historically was always seen as a disease state," he says. As one who admits to some neurotic traits himself, he rather resents the happy talk: "The idea was, we had to cure this condition and turn everyone into a happy-go-lucky bunny, hopping around, saying, 'Hello, sky!' "

In 2015 Perkins and some colleagues wrote a journal article arguing that the conventional self-help theory of creativity gets the psychology exactly backward. These researchers say neurotics don't need to be freed from their misery to be creative; on the contrary, they should embrace it. Far from killing creativity, neuroticism feeds it.

Their reasoning is rooted in a long-standing model for how personality works. For decades, psychologists have classified people according to five fundamental traits that appear to be consistent throughout life, which students memorize with the initialism OCEAN: Openness to experience, Conscientiousness, Extraversion, Agreeableness and Neuroticism. People who score high on measures of Openness like to do new things and entertain unexpected thoughts, and they're not big on routine and rote. People who score high on Conscientiousness will keenly feel their obligations to other people—they tend to meet deadlines and pay attention to detail. Extraverts are talkative and outgoing; people who score low on this measure are shy. Agreeableness scores reflect how empathetic and other-oriented a person is. (People who score low on this measure don't care much about others' feelings.)

Unsurprisingly, creativity—the ability to fashion

something valuable that's never been seen before—has been linked to openness to experience. But, Perkins says, openness alone is not enough. After all, you don't need to invent new things to have new experiences. You can just walk down a street you've never been down before, or try something new on a menu. Appreciating a new thing is a lot less complicated than creating one. "Oh, wow" is not the same as "Eureka!"

"People with high openness to experience, they have imagination, but it's this dreamy here-and-now experience, rather like a mini LSD trip," Perkins says.

Creations, whatever their form (new rhyme, new theory of rice genetics, new way to sell fidget spinners, new microchip design, etc.), aren't discovered until people are wrestling with a question (what rhymes with "orange"? how could we make the same chip for less?). In other words, to see a solution, you have to think about a problem. And when it comes to thinking about problems, neurotics are champions. Psychological tests for neuroticism pose questions like "Do you ever feel 'just miserable' for no reason?," "Do you worry about awful things that might happen?" and "Do you worry too long after an embarrassing experience?" Neurotics are the people who answer yes.

A common explanation for this in psychology is that neurotics are unusually sensitive to threats. You won't find many fighter-jet pilots who score high on neuroticism tests, for instance, because neurotics tend to go for safer occupations. (They also take fewer risks of all sorts, from hobbies to finance.) But Perkins and his colleagues think this definition fails to capture the root of neuroticism. After all, he says, "it's perfectly normal to be anxious when someone has a gun to your temple. A hallmark of highly neurotic people, though, is that they have a kind of virtual-reality world in which they're worried about that gun to the temple but there is no gun."

To understand how different parts of the brain interact to create our thoughts and states of mind, researchers often put research subjects into brain scanners and have them perform a particular task. By observing which areas of the brain are more active than usual while a person counts or remembers names or listens to Mahler, the scientists can ascertain what regions, and networks of regions, are involved in that kind of mental experience.

Some years ago, this technique accidentally discovered a network no one was looking for: one that

is active when people don't have anything to do in the scanner and are simply at rest, letting the mind go where it will. This "default network" is what's active when we're daydreaming or ruminating quietly. Everyone has such a network, but not everyone has one that is tuned to sad thoughts and troubling problems. Perkins and his colleagues believe neurotics are people whose default networks are pitched toward the negative. This, they say, is a better explanation of neurotic behavior than the prevalent neurotics-are-more-sensitive-to-threats explanation.

"A hallmark of neurotics is that they tend to fall into this blue-tinged problem-focused state," Perkins says. The thing about these miserable mopings, he explains, is that they cause neurotics to spend more time imagining situations that don't exist. Spurred by their tendency to ponder bad things that could happen, neurotics spend a lot of time mentally traveling through possible futures. The upside is that this helps them to imagine new and valuable solutions to problems.

"I keep the subject constantly before me, and wait till the first dawnings open slowly, by little and little, into a full and clear light," wrote Sir Isaac Newton, another geyser of scientific creativity who was famously nasty and more than a little weird. Perkins, who likes to quote that passage, says it's a model for

the way neurotic miseries feed innovative thought. It was because Newton, Darwin and other creative people imagined problems where others saw only sunny skies, he argues, that they achieved their breakthroughs.

NO ONE DISPUTES THAT NEUROTICS IMAGINE PROBlems that others don't see. But are they the right problems? Shortly after Perkins and his colleagues published their theory in 2015, a trio of psychologists—Alan D. Pickering, Luke D. Smillie and Colin G. DeYoung, writing in the same journal—said the answer is no.

The doubters argued that the neurosis-creativity theory is just an academic version of the old stereotype of the tormented creative genius. Yes, they wrote, there's some association of artistic ability and mental disorders. But those afflictions—bipolar disorder, major depression and the like—are not the same as everyday neurotic tics.

Focusing on that sort of neuroticism, they said they'd found no evidence that it is associated with real creative achievement or even a high score on measures of creativity. That's no surprise, the skeptics wrote, because people with a lot of negative thoughts and feelings can't control them. In other words, a neurotic ruminating on her day is more likely to be worrying about some embarrassing incident at the coffee counter than the big problem she needs to solve by Tuesday.

That means neurotic mental experiences are probably a distraction from, not an aid to, creative breakthroughs. Rather than being the source of both neurosis and creativity, a neurotic's default network has probably been commandeered by the real drivers of neurosis elsewhere in the brain, the skeptics say. Brilliant neurotics, Pickering and his co-authors wrote, "seem likely to have achieved their intellectual creativity despite their neurotic personalities rather than because of them."

There's no doubt that some people, like *The Artist's Way* author Cameron, feel their creative pursuits are an escape from their neurotic thoughts, not a result of them. Darwin, for one, didn't think his feeling stupid and hateful led to insight. Instead, he wrote, "my chief enjoyment and sole employment throughout life has been scientific work; and the excitement from such work makes me for the time forget, or drives quite away, my daily discomfort."

Perkins, though, is standing by his claim, saying he has found links between high scores on neuroticism and creativity. For example, a recent study he performed on financiers in the City of London found that the best performers were those who scored highest on measures of both IQ and neuroticism. (Neurotics with relatively low IQ scores, however, were among the least successful, he adds, illustrating that more than one factor must be involved.)

It's not easy for non-specialists to suss out who is right in this debate. The problem is that psychologists don't have a creativometer or a neuroticograph. These traits are measured indirectly—by asking people things like "Do you ever wish you were dead?" (one of the questions that helps determine your neuroticism score on a common assessment exam) or "How many uses can you find for this brick?" (a common measure of creativity in lab experiments). Making a connection between traits like creativity and neuroticism means having an argument about exactly what the terms mean and whether they are correctly measured. Does it make sense to say that a successful financier is more creative than one who isn't? Does it make sense to say a student who finds more uses for a brick is more creative than one who doesn't? Not everyone agrees, in psychology or outside the field.

Does a neurotic's tendency to ruminate enhance or hinder creative thinking? Experts disagree.

So Perkins argues that real-world creativity, where the stakes are real, is different from asking hypothetical questions of undergraduates in a lab. On the other hand, the skeptics maintain that it's a stretch to argue that debilitating feelings like "I wish I were dead" lead to imaginative thoughts about possible worlds.

"I'm not saying neuroticism is the only thing that influences creativity," Perkins replies. "High IQ is necessary. Openness to experience, an external situation that calls for creative thought, and neuroticism—any of these factors is necessary but not sufficient. Maybe we should be keeping an open mind. Rather than choosing one theory, maybe both are correct."

A FINE MADNESS

Between 1949 and 1964, Lowell was hospitalized 12 times for bipolar disorder, often for months at a time.

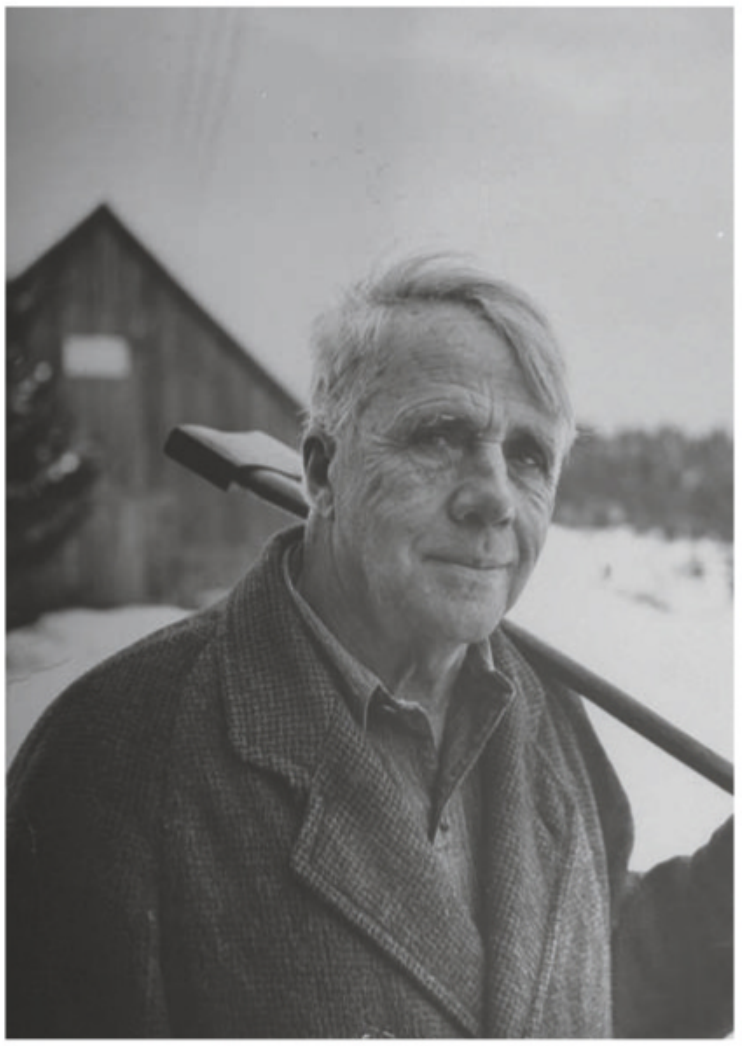
POET ROBERT LOWELL WAS ONE OF A LONG LIST OF CREATIVE GIANTS WHO GRAPPLED WITH SERIOUS MENTAL ILLNESS

BY KAY REDFIELD JAMISON

ROBERT LOWELL, RANDALL JARRELL AND JOHN Berryman were " brilliant, mordant and lighthearted young men," recalled the classicist Robert Fitzgerald at Lowell's memorial service in 1978. And in the late 1940s, they were poets in a class by themselves. "They faced the age of anxiety with nerve and love, and they had hard lives." Hard lives, indeed: Berryman killed himself and so, almost certainly, did Jarrell. It seemed a uniquely blighted era of writers; manic breakdowns, depression, addiction, alcoholism or suicide struck, among others, Hart Crane, Vachel Lindsay, Edna St. Vincent Millay, Ezra Pound, Robert Frost, Sylvia Plath, Anne Sexton, Delmore Schwartz, Theodore Roethke, Elizabeth Bishop, Virginia Woolf, Graham Greene, Eugene O'Neill, Tennessee Williams and William Carlos Williams. Allen Ginsberg, himself no stranger to instability, began "Howl" with words that would be repeated by a river of followers: "I saw the best minds of my generation destroyed by madness."

Lowell was acutely aware of the mental problems that haunted him and many of his contemporaries. He and Roethke often wrote to each other about the toll mania and depression had taken on both of their lives. "I, too, am just getting over a manic attack," Lowell reported. "Everything seemed to be going swimmingly, then suddenly I was in the hospital—thorazine, windy utterances, domestic chaos . . . Now it's passed; I'm back typing in my study; my feet are on the floor." In 1976, the year before he died, Lowell became manic again—and again had to be committed to a hospital. Perhaps it was "the price one pays for being such a rich, inventive and variegated writer," wrote the poet Philip Larkin. "I only wish I had one-eighth of his creativeness."

Lowell and his contemporaries were far from the first to observe that a germ in the mind, some flaw in the motor, rocks the lives of poets—the early Greek philosophers had described it as a "divine madness."



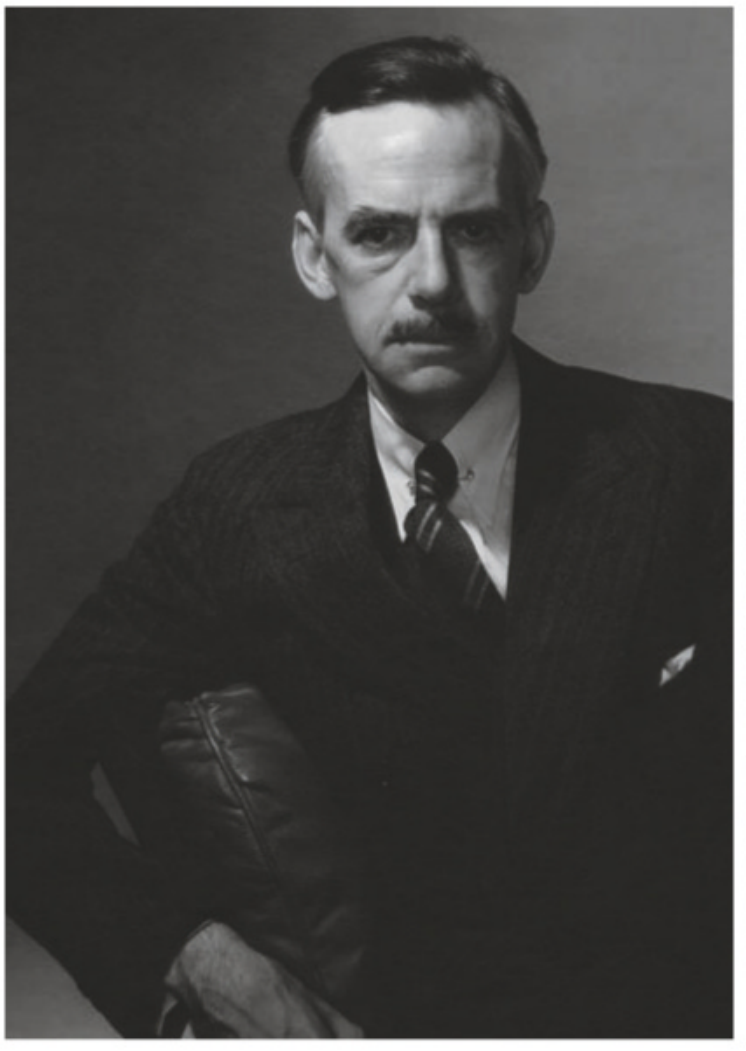
Tormented literati (from left): poets Robert Frost, Allen Ginsberg and Sylvia Plath, playwright Eugene O'Neill and novelist Graham Greene

The excitable mental state we know as mania was believed by the philosophers and doctors of antiquity to make minds and senses keener; it heightened the power of observation, they suggested, and yoked passion to discovery and imagination. Mania intensified and sped the mind, forced it into places it would not otherwise go. For more than 1,000 years—in clinical papers, asylum records and correspondence—doctors noted enhanced memory and originality in their manic patients.

Dr. Benjamin Rush, "father of American psychiatry" and a signer of the Declaration of Independence, wrote in 1812 that when patients are manic, "the senses of hearing and seeing are uncommonly acute." Knowledge long buried could be "resuscitated," new talents could emerge: Where is the hospital for mad people, in which elegant and completely rigged ships, and curious pieces of machinery, have not been exhibited, by persons who never discovered the least turn for a mechanical art previously to their derangement? John Campbell, author of an excellent 1953 clinical textbook on manic-depressive illness (now known as bipolar disorder) observed that mania often led to a propulsive drive to write: "Urged on by the pressure of ideas as well as an excess of physical energy."

Is there a fundamental link between "madness" and creativity? Research is at an early stage, but several lines of evidence make an increasingly persuasive case that the answer is yes. Since the mid-20th century, numerous studies have found a much higher rate of psychosis—usually mania—in writers, artists and musicians than in the general population. Poets are the most likely to have a history of mania. In 1987, Nancy Andreasen, a psychiatrist at the University of Iowa, studied 30 members of the Iowa Writers' Workshop and found that fully 80% met diagnostic criteria for a mood disorder; most strikingly, nearly one half met the criteria for bipolar disorder. Indeed, writers were more than 10 times as likely as the general population to be diagnosed with bipolar I disorder, the more severe form of the illness. They were also more likely to kill themselves.

A few years after Andreasen's study, I published a paper on 47 eminent British artists and writers and found that more than one third had been treated for depression or mania. All who had been treated for

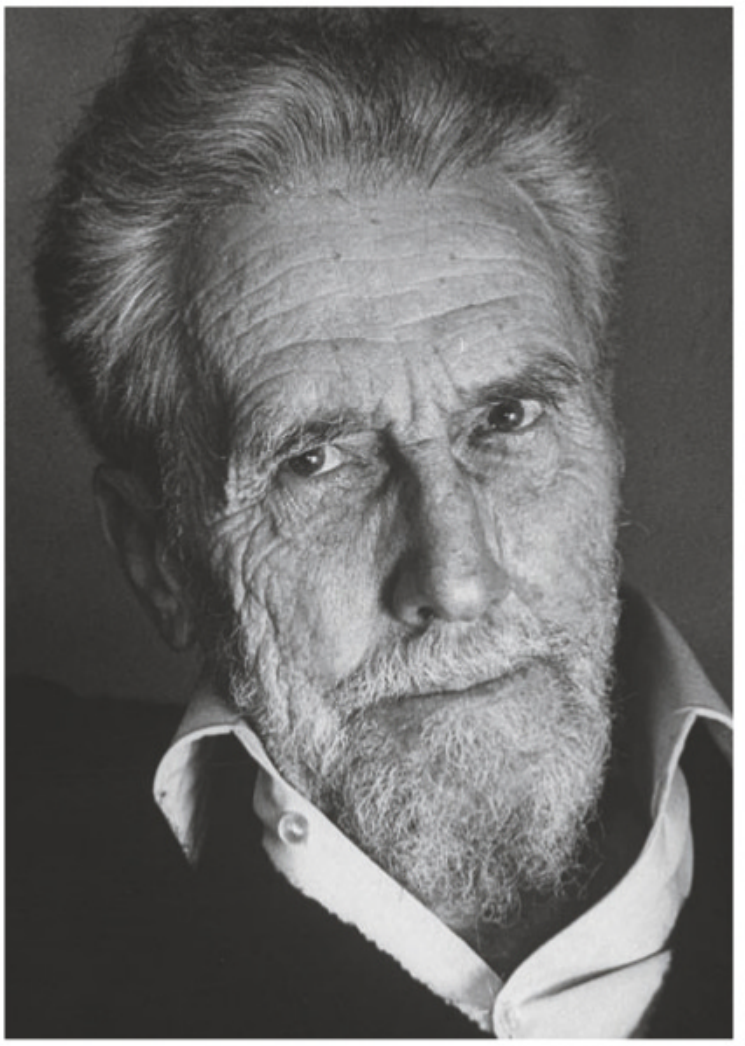


mania were poets. Most reported their intense moods were essential to their creative work. Many studies before and since have found high rates of depression and mania in highly creative people. A 2010 study of more than 20,000 found that subjects with bipolar illness were disproportionately concentrated in creative jobs—writing, the visual arts and music—a result consistent with two much larger Swedish studies published shortly thereafter. (Each involved hundreds of thousands of individuals.)

Is there a link between "madness" and creativity? Evidence makes an increasingly persuasive case that the answer is yes.

WHAT IS IT ABOUT BIPOLAR DISorder that can abet creativity? Mania is generative; it speeds the mind and fills it with words, images and possibility. It ties together distant thoughts and blasts buried recollection into consciousness; it brings to awareness that which otherwise would pass unregistered, unfelt, unwritten. Mania infects with the certainty that newly generated ideas are important and must be shared. Mania provokes the appalling and the violent and, now and again, partakes in creating that which is beautiful. The elated mood that usually accompanies mania disinhibits, makes the taking of risks and exploration more likely and creative combination of ideas more probable. To be in the grip of mania is to experience the unimaginable, try the unthinkable, do the unforgivable. The symptom of mania referred to as "flight of ideas," is characterized by a torrent of near-unstoppable speech; thoughts brachiate from topic to topic, held only by a thin thread of discernible association. Ideas fly out, and as they do, they rhyme, pun and assemble in unexampled ways. The mind is alive, electric.

When Robert Lowell was well, which was most of the time, his mind was fast, compound, legendary in its depth of his knowledge, a labyrinth of myth and language and experience. When mania attacked, it set afire a brain rare in its capacity, seriousness and discipline. Mania did not make Lowell a great poet; he was that before he was ever recognizably manic. But it was a determining force at times, driving rhythm and content. And, after long-drawn-out periods of no writing, it disturbed the embers and breathed back the life into his poetry.



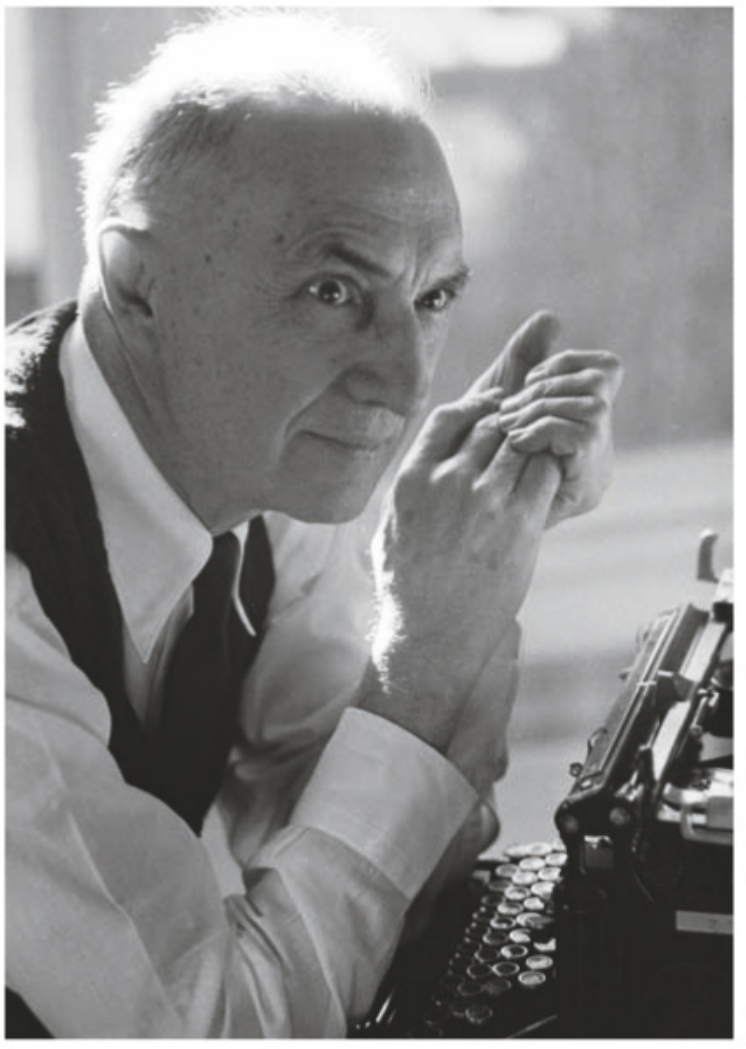
Poets plagued (from left): Anne Sexton, Ezra Pound, Edna St. Vincent Millay, William Carlos Williams and Randall Jarrell

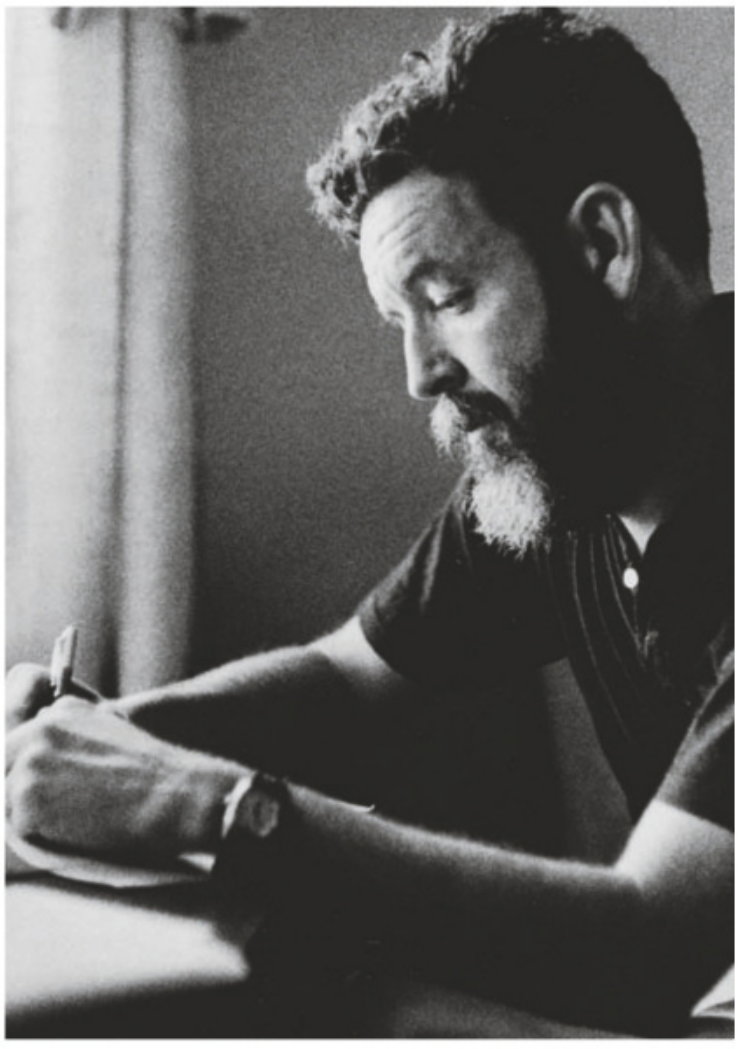
Certainly creativity can be sparked and enhanced by the expansive mood and grandiosity that are so often a part of mania. Artists and writers—including the majority in my British study—often report that elevated mood precedes periods of intense creative work. These heightened states were characterized by ease and speed of thinking and the effortless generation of new ideas.

If periods of high mood drive creativity, intense creative work may escalate mood yet higher. For those prone to mania, that carries serious risks. As early as 1943, Lowell's mother blamed his poet friends for pushing him over the edge into mania with the "emotional excitement of poetry." The overheated poetic brain has long been a topic for physicians and philosophers. "Men of genius," declared Thomas Middleton Stuart in an 1819 essay, "Genius and Its Diseases," are like "some noble bird of heaven, stretching its flight towards ethereal regions, which soars and soars, unconscious of fatigue and reckless of danger, till it dies in the clouds."

To be sure, euphoric mania is an intoxicating state of mind: exuberant, exalted and inclined toward a sense of cosmic relatedness. But mania, whatever its relation to art, is also a serious illness; the delusions and hallucinations that often accompany it make this particularly clear. Delusions—fixed, false, idiosyncratic beliefs—marked Lowell's attacks of mania from the time he was first ill until his final episodes in the year before he died. This is more common than not in mania; half of those who have been manic have been delusional at one time or another. Of those who have been delusional, half have had grandiose delusions and half have had paranoid delusions.

Lowell's delusions were overwhelmingly of the grandiose type. He was at times Christ, the Holy Spirit, Achilles, Aeneas, Saint Paul, Alexander the Great, Napoleon, King James IV, Hitler, Henry VIII, the Messiah, John the Baptist, Dante, Milton, Julius Caesar, T.S. Eliot. He knew these figures well, their work better. They were creators and destroyers: gods, heroes, tyrants and saints. When he was manic, Lowell entered their world; he assumed their rage and took on their charms, saw the Devil and smelled the brimstone: felt keenly the danger in which the world hung, hacked his way through the walls of his house looking for the Etruscan treasures he knew had been hidden there. At times, the Devil and brimstone were meta-





phoric; when he was mad, they were real. "It is hard to say what you can put into poetry," he told an interviewer in Maine. "It has to be something you've lived."

With distance from his illness came the opportunity to use slivers of his delusional experience for poetry; the backward look discomfited. "What can you do after having been Henry VIII or even a cock of the walk weekly sheriff?" he wrote to Peter Taylor. "You get beautifully your character's living for the moment he is seen or heard. All life for the flashes! Everyone has a lot of that, and we writers more than most, only the words, the structure, the tune come out of us, are us." Lowell's delusions came from the dangerous, as well as the extraordinary, elements within memory, shredded and rearranged, in many ways apropos of nothing. Delusions are like the bits of recollection and perception that push to the surface during delirium or dreams. But unlike delirium, they usually coalesce into a story. Lowell's delusions came as well from his personally registered history of the world; his loves and his convictions; his deep reading of poetry, classics and history.

Studies have shown that writers are 10 times as likely as others to suffer from the most severe form of bipolar disorder.

His psychosis, although beyond his control, was beholden to the specifics of his life and to the intricate minuet and genius of his brain; when he recovered, he would change and chisel the poetry he had written when he was manic. Parts were unsalvageable, others radically original. Mania gives rise to "new and wonderful talents and operations of the mind," wrote Benjamin Rush in 1812. It can be compared to an earthquake, "which by convulsing the upper strata of our globe, throws upon its surface precious and splendid fossils, the existence of which was unknown to the proprietors of the soil in which they were buried." Any attempt to understand Lowell's work must necessarily be "more seismographic than aesthetic." Upheaval was beyond the will; the discipline to shape it was not. Imagination was somewhere in between.

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THE POWER OF SLEEP

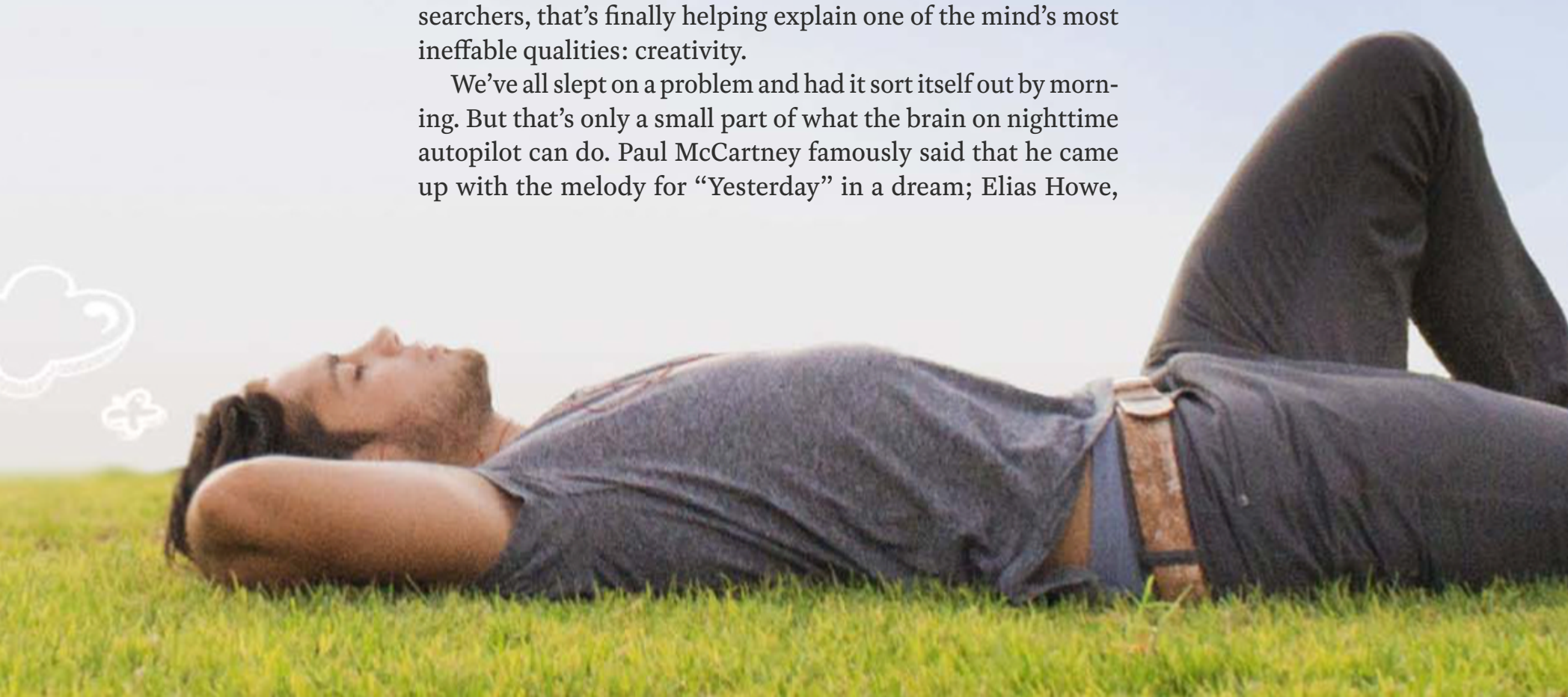
OUR UNCENSORED, SLUMBERING BRAINS CAN DREAM UP LIMITLESS VISTAS

BY JEFFREY KLUGER

SLEEP IS, AS ANCIENT MAPS ONCE LABELED UNCHARTED TERritories, where dragons be. To go to sleep is to enter a world entirely like our own and entirely unlike it, too. You can board a plane that's really a car that flies to Russia, except it's the moon and your mom is there—until she's your dad. Dreams can be prosaic or repetitive (exactly how many times can you show up at the same party in your underwear before you remember to put something on?), but whatever they are, they remain mysterious. The sleeping brain runs its absurdist-movie loop all night long, always concealing the processes going on behind the camera.

No longer. Neuroscientists have a growing arsenal of imaging tools to watch the nocturnal brain at work and see how it ticks throughout the sleep cycle. To the surprise and delight of researchers, that's finally helping explain one of the mind's most ineffable qualities: creativity.

We've all slept on a problem and had it sort itself out by morning. But that's only a small part of what the brain on nighttime autopilot can do. Paul McCartney famously said that he came up with the melody for "Yesterday" in a dream; Elias Howe,



the inventor of the sewing machine, is said to have solved the problem of the machine's needle when he dreamed of an attack by warriors carrying spears with holes in the tips. "Dreams are just thinking in a different biochemical state," says Harvard University psychologist Deirdre Barrett, author of *The Committee of Sleep*. "In the sleep state, the brain thinks much more visually and intuitively."

The hunt for the source of human creativity has been going on for as long as people have been creating, and it's no secret that sleep can be a well of good ideas. What we're learning now is how to dip into it.

The act of sleeping, as researchers have long known, is a lot more complicated than just conking out for the night. There are two principal cycles of sleep: rapid eye movement (REM) and non-rapid eye movement (NREM), and they alternate. NREM sleep starts as a light doze—sleep at no greater than snorkeling depth—and steadily progresses to deeper levels, at which muscles relax, heart rate and respiration slow and body temperature drops.

REM sleep usually begins about 90 minutes after the start of the first NREM cycle and is the real blue ocean of sleep. Heart rate and respiration accelerate, and brain activity, as measured by electroencephalograms (EEGs), increases too—a function of dreaming. For this reason, muscles become paralyzed, lest you act out the scenes unspooling in your head. Know those dreams in which you're trying to run away from something but can't seem to move your legs? That's not your imagination.

Most REM sleep comes in the last four hours of slumber, says cognitive neuroscientist Jessica Payne of Notre Dame University. "Dreams in the early, NREM phase can be kind of literal. It's in the REM phase that you get all these crazy binding errors."

"Binding errors" is one of those scientific terms that mean pretty much what they sound like. Your waking brain is orderly, your sleeping brain is fragmented—and the bits can get reassembled the wrong way. But "the wrong way" suggests that there's just one way, and the genius of sleep is that it allows you to explore other, untried avenues.

In a frequently cited 2009 study, investigators at UCLA and the University of California, San Diego, recruited a group of volunteers and had them solve word puzzles. The volunteers had to take the test twice, with a 40-minute nap in between. Some just rested in that interval, others dozed, and some tumbled into the depths of REM sleep. In Round 2 of the tests, participants who got a slug of REM improved 40%, while the other volunteers saw their scores go down. Sleep, it appeared, sharpened their brains' ability to find links among words.

A 2004 study from the University of Lübeck in Germany approached the same idea in a more revealing way. Subjects were required to complete math problems that relied on algorithms, but hidden deep within the formulas was an elegant arithmetical shortcut. About 25% of the subjects discovered it on their own. But that figure jumped to 59% when volunteers were given a chance to get eight hours of sleep and then come back for more.

During REM sleep, the brain becomes fragmented, reassembling bits and pieces of scenes and images in strange ways.

"If you have an idea about a simpler solution and it's been working itself out in your head, you still tend to use the familiar one," says cognitive neuroscientist Howard Nusbaum of the University of Chicago. "When you sleep, the better answer has a chance to emerge."

THE KEY TO THE BRAIN'S ABILITY TO make such good use of downtime is something it shares with your computer: the capacity to run multiple programs at once. The "aha" moment when you've been trying to remember a song title and three hours later it hits you is a result of that. "Conscious awareness is able to focus on only one thing at a time," says Barrett, "but problems go on getting processed under the radar."

Sleeping doubles down on this. The prefrontal cortex performs a traffic-cop role, keeping the brain focused on a conscious task but also screening out thoughts it deems socially or rationally inappropriate. In sleep, that brake on your imagination comes off, which explains the German math study.

At the same time the prefrontal censor is dialing itself down, the brain's visual centers, in the occipital lobe at the back of the head, are dialing up. The hallucinogenic quality of dreams is a result of the visual centers' mixing images at will. That's usually just chaff, but not always. One night in 1816, Mary Shelley dreamed of a man assembled from bits be-

yond the grave—and went on to write *Frankenstein*.

Just as important as which regions of the brain are working is how they communicate. We think of the left hemisphere as the rational, mathematical region and the right as the creative, more bohemian one, and that's a fair if vastly overgeneralized division. But a study conducted by neuroscientist Lisa Aziz-Zadeh of the University of Southern California found that the brain is much less bifurcated than believed.

When architecture students undergoing functional magnetic resonance imaging (fMRI) brain scans were asked to perform a visual-spatial task—arranging geometric shapes in their heads to see if they could be assembled into a square or a triangle—the right, artistic hemisphere carried the load. Given a slightly more creative task—arranging a circle, a C and an 8 in various ways to form a face—the right hemisphere called on the assistance of the left. "The specific regions that are active during the creative process largely depend on the kind of task the person is engaged in," says Aziz-Zadeh.

Another study, at the University of Rome, found something similar. With the help of EEGs, investigators tracked communication between hemispheres when subjects were awake, in NREM sleep and in REM. In the waking and NREM states, information traveled mainly from left to right, consistent with the idea that the left brain controls the right. During REM sleep, however, there was no preferred direction. The right can thus come out of the shadows.

Synapses—the cell-to-cell links that serve as the bits of the brain's operating system—play an important role too. Each brain cell can link to many others, and it would seem that the more connections there are, the better, since that makes for a richer system. That's true to a point. Too many connections can lead to chaotic free association rather than organized thought. The brain must periodically clear out the synaptic underbrush—analogous to "running a repair-and-cleaning program on your computer to defrag the hard drive," says psychologist William Killgore of the University of Arizona.

The hormone cortisol rises during REM and then helps form new and imaginative ideas from the data that survive the defrag. Cortisol is a stress hormone and tends to fracture memory. It has the same effect when we're asleep, and Payne believes this encourages the unbinding and rebinding of images that can define dreams. "The brain dislikes fragmentation, so it weaves narratives," she says. "And that, in turn, gives rise to novel thinking."

Dopamine is another ingredient in the brain's secret creative sauce. Harvard University psychologist Shelley Carson, author of *Your Creative Brain*, points out that dopamine levels rise in the brain's pleasure centers both when we're dreaming and when we're being creative. This serves as a reward and reinforcement that keeps the dreams—and ideas—flowing.

Dopamine levels rise in the pleasure centers of the brain both when we're dreaming and when we're being creative.

As with all matters scientific, the question of causation arises. Are we all equally imaginative in our sleep, or do people who are creative in waking hours retain an edge at night? The answer maybe the latter. Psychologist David Watson of the University of Notre Dame tracked 200 subjects over three months and found that those who scored high on creativity scales when awake tended to remember their dreams more. "One reason is that they simply have more vivid and interesting dreams," he says. "That's linked to having an active fantasy life; the daytime behavior shades over into the night. This is a case of the rich getting richer."

That's not to say the creative middle class can't aspire to join that metaphorical 1%. The best strategy for remembering dreams is keeping a journal next to your bed, says Watson. Also suggested is avoiding alcohol and caffeine, which scramble the NREM and REM cycles. Engaging in some pre-bedtime priming—contemplating a problem you'd like to solve—increases the likelihood that sleep will bring some answers. Up to a third of the subjects in one of Watson's sample groups reported that priming had helped them find a solution that had eluded them during the day.

None of this guarantees that a good night's sleep is the panacea for what ails you creatively. But neither does it change the fact that the odds are in your favor. You have problems every day, and you go to bed every night. But even if you don't think of yourself as creative, your sleeping brain will sometimes prove otherwise.

INSIDE THE CREATIVE SPACE

WHERE SOME GREAT ARTISTS AND WRITERS COMMUNED WITH THE MUSE

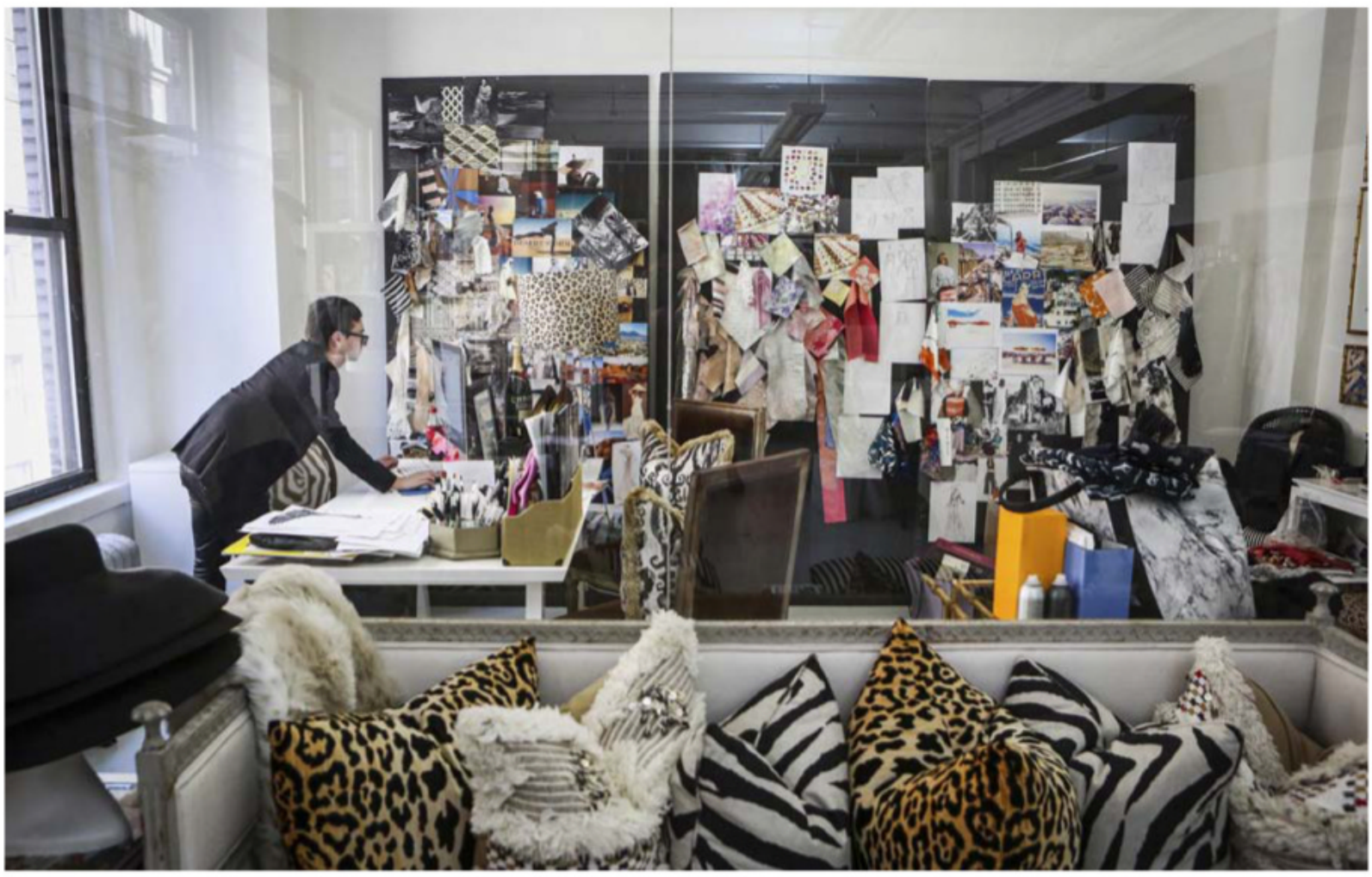
BY RICHARD JEROME

"AN ARTIST'S STUDIO SHOULD BE A SMALL SPACE BE-cause small rooms discipline the mind and large ones distract it," Leonardo da Vinci once said. It's hard to argue with the supreme Renaissance genius; still, contemporary British artist David Hockney might beg to differ: vibrant and productive at 81, he works out of an airy converted paddle-tennis court. The dichotomy shouldn't be surprising. Historically, creative spaces have varied according to their occupants' unique personalities—and idiosyncrasies. Think of your own ideal work environment. Where do you feel free to let your imagination run wild—yet also focus on the task at hand, whether it's painting, writing, solving math theorems or making out the monthly bills? You may thrive in a spare, tidy setting—or else (like this writer) amid piles of books, papers and empty coffee cups. Some of us demand solitude, shielded from humanity's hubbub, somewhere in nature, perhaps. Some find stillness insufferable, can't bear the chirps of crickets or birds, and produce best amid the urban din. J.K. Rowling famously wrote her early Harry Potter novels at Elephant House and Nicholson's, two Edinburgh cafés.

The following pages offer a glimpse into some world-class creative spaces, each one as distinctive as the creators themselves.

Alexander Calder in his rural Roxbury, Conn., studio. The sculptor moved there in 1933 and converted the ice house behind his home into a workshop, which allowed in breezes that kept his signature mobiles twirling.

USAF
CAUTION RADIATION
AVENGERS
STAR TREK



Clockwise from top left: A buffalo hunting trophy hangs over the Havana desk where Ernest Hemingway produced The Old Man and the Sea*; movie studio artists John Goodson and Bruce Holcomb at Industrial Light & Magic in San Francisco; Victor Hugo wrote* The Hunchback of Notre Dame *at this standing table in the Channel Islands, where he lived in exile after opposing Napoleon III; English painter, photographer and printmaker David Hockney in his Hollywood Hills studio; designer Christian Siriano (with mood board) at work in NYC's Garment District*

Andy Warhol in 1965, at his Silver Factory in midtown Manhattan, where he produced paintings, prints and parties

Georgia O'Keeffe in 1945 moved into an abandoned Spanish Colonial–era compound in Abiquiú, N.M.

Abstract Expressionist Jackson Pollock in 1949, at work in his unheated, windowless converted barn on Long Island

Visionary architect Frank Lloyd Wright (in 1956) at Taliesin, his home in Wisconsin that he rebuilt three times

CHAPTER THREE

CREATIVITY IN ACTION

IT TAKES MANY FORMS, APPLYING TO VIRTUALLY EVERY REALM OF EXPERIENCE

"My creative process is centered around the need for a strong idea. The best way for me to get to that idea is to take as much of my own creative anxiety/baggage out of the process and to approach the subject with empathy. At best, I hope to imagine the thoughts, emotions and visuals that surround the subject."

—Brian Stauffer

As a contributing artist to hundreds of publications worldwide, Stauffer has made award-winning illustrations best known for their conceptual take on social issues. Through a unique combination of hand-drawn sketches, painted elements and scanned found objects, his work, an example of which is at left, bridges the traditional and digital realms.

SEVEN SECRETS TO UNLEASHING YOUR INNER GENIUS

A PSYCHOLOGIST SERVES UP SOME TIPS TO HELP FREE UP THE MIND AND STOKE THOSE CREATIVE FIRES

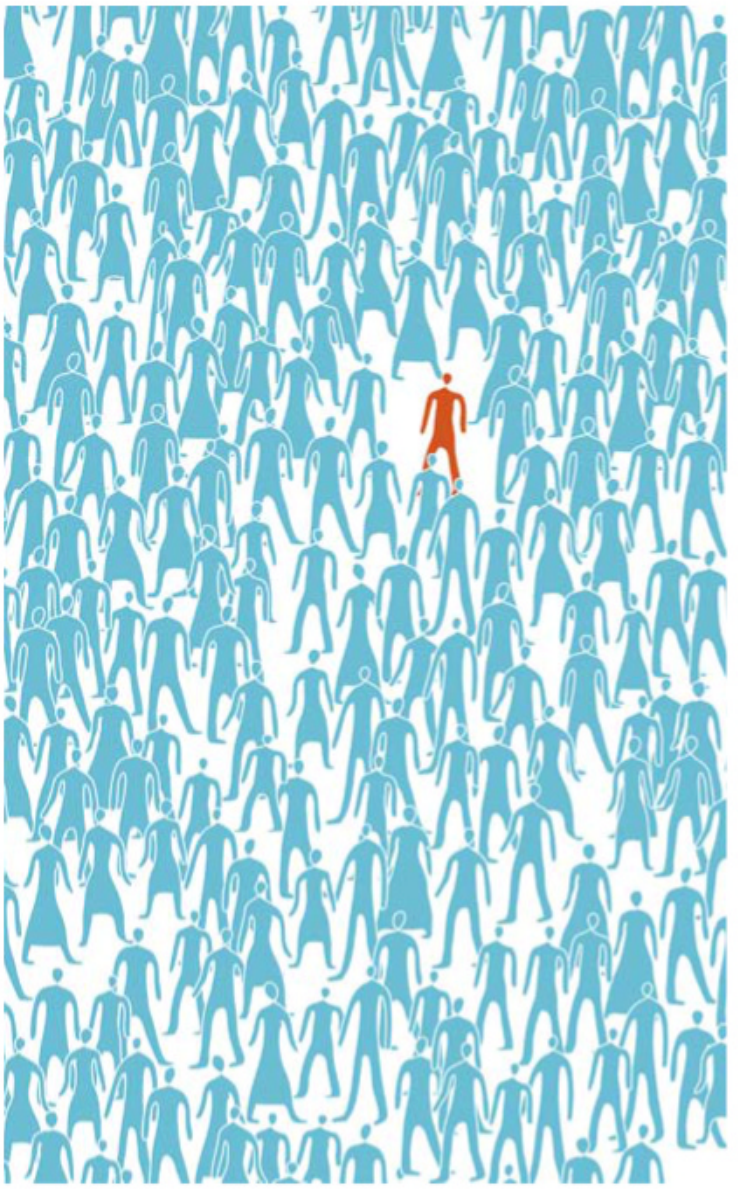
BY COURTNEY MIFSUD

DR. SCOTT BARRY KAUFMAN—A RESEARCHER, PSYCHOLOGIST and co-author of *Wired to Create: Unraveling the Mysteries of the Creative Mind*—has spent years studying humanity's unique penchant for innovation and offers some advice for living a more inspired life. Written with journalist Carolyn Gregoire, *Wired to Create* examines the recent science surrounding creativity and reveals that the process is often messy and rife with contradictions. For example, the book describes Pablo Picasso's method of painting *Guernica*—his powerful 1937 depiction of the Nazi-Fascist bombing of a Spanish village—as "more chaotic than controlled, more spontaneous than linear." As the artist himself explained it, "A painting is not thought out and settled in advance. While it is being done, it changes as one's thoughts change. And when it's finished, it goes on changing, according to the state of mind of whoever is looking at it."

Of course, few of us are as sublimely gifted as Picasso—or Newton or Beethoven. But as Kaufman tells TIME, creativity is more than a matter of natural talent. It's also a state of mind, "a certain attitude that you can bring to any task, a general spirit of spontaneity and questioning the world and the way things work—seeing things continually fresh and new, that you may have seen many times before. It's a certain way of being in this world." Here, Kaufman offers seven keys to help unlock your own innate creative potential:

1.
DON’T FORCE INSPIRATION.

Sometimes you have a deadline that compels you to be creative, or a task that requires some imaginative elements. But focusing on goal-driven production may backfire. “Inspiration is not something willed. It’s hard to wake up in the morning and say, ‘I’m going to be inspired today.’ The more you try to force it, the less likely you are to start,” says Kaufman. “You need to create a space for people to discover things about themselves.”



2. UNDERSTAND THE BIAS.

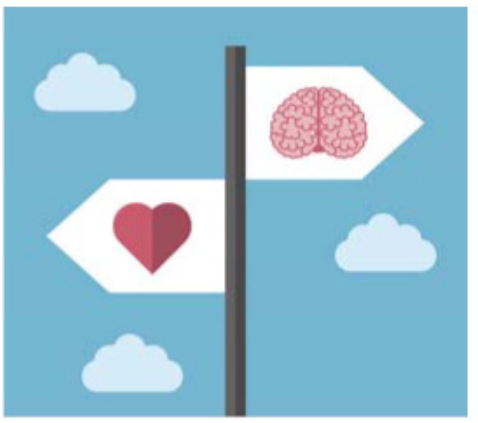
Whether they're in elementary school or a corporate office space, people who think and process in unique or creative ways might feel stifled by conforming to traditional means of production output. "We do seem to be biased in most schools and workplaces against individual expression and unique choice," says Kaufman. "That sort of standardization of behavior is really a killer of creativity." How can students and nine-to-fivers overcome confining and rigid structures? By trusting in your own intuition when you show enthusiasm or excitement in something new, and then finding some kind of outlet to express it.

3. BREAK BEYOND IQ.

"Standard ways of thinking about intelligence leave out the whole person," says Kaufman. "They leave out the passions or the values that one holds, the personal goals and dreams that someone has and what they want to achieve, as opposed to imparting a certain task on the person." Frank X. Barron, a psychologist who pioneered the study of creativity in the 1960s, broke away from the longtime assumption that intelligence was the essential trait of highly creative people. Scientists now agree with Barron that to understand creativity, you need to look beyond the IQ test. "There's this traditional notion of intelligence solely comprising cognitive information processing, like we're robots, our ability to problem-solve abstract information," says Kaufman. "But I do think that's a hindrance, because intelligence is more broadly an adaptation to our environments, and the creative thought processes that come into play are so connected to being able to adapt to any environment, not just for abstract information that is derived from your everyday life."

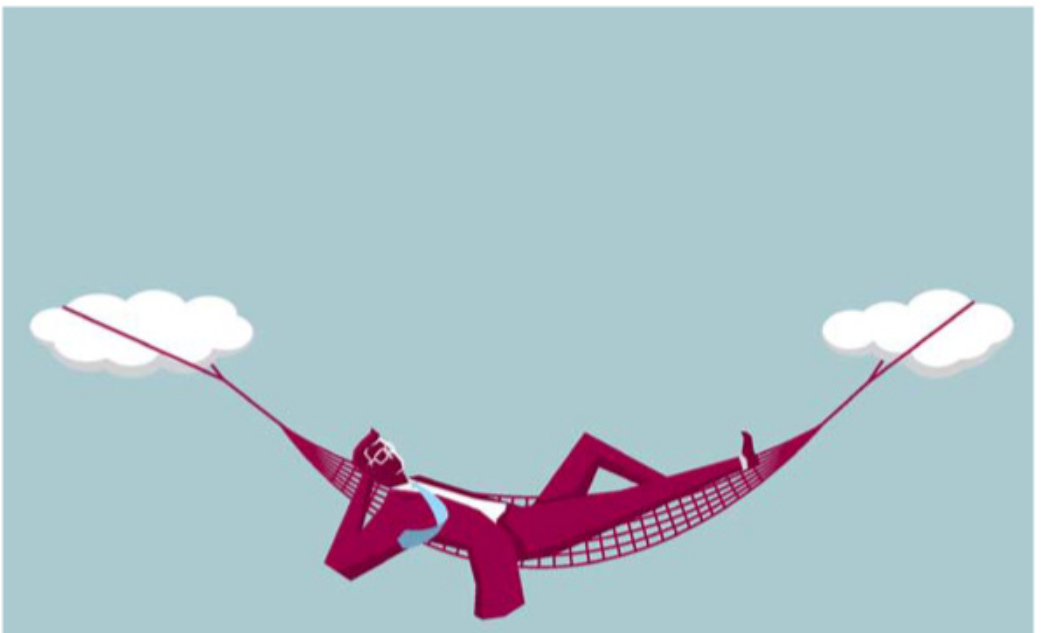
4. BE OPEN TO NEW EXPERIENCES.

According to Kaufman, you need to create a space where you can discover things about yourself, and that is most likely to happen when you leave yourself open to new experiences. And what exactly does that mean? At the core it's "the drive for exploration and curiosity, and the constant temptation to get outside your comfort zone and embrace the unknown," Kaufman explains. "In your everyday life you could be open to new experience in any moment. Try as best as you can to keep your prior stereotypes and anxieties [to yourself] and try not to impart them onto the world. Try to see things as they truly are—and be curious about everything. Be curious about anything."



5. EMBRACE OPPOSING FORCES.

Highly creative people tend to welcome paradoxes, melding two seemingly contradictory ideas that lead to greater innovation. "There are a lot of so-called dichotomies that aren't really dichotomies at all," says Kaufman. For example, when it comes to the creative process, there's no sharp demarcation between work and play. Other lines blur as well. "People who are really creative are good at trusting and having faith in their intuition but also at being rational in their analysis of whether or not something is correct." Strength and sensitivity also seem contradictory, but the distinction may not always be so clear. "Creative people tend to have extraordinary sensitivity but also are capable of staying true to their values, even in challenging environments." Highly creative people have a tendency for post-traumatic growth, an ability to learn from distressing experiences.

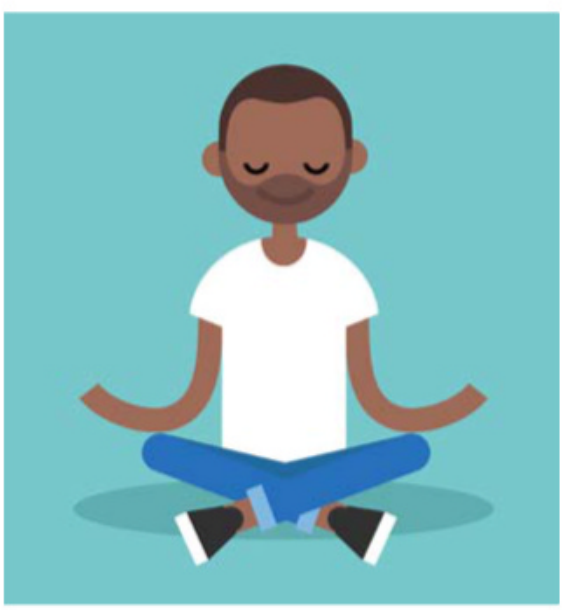


6. LET YOUR MIND WANDER . . .

One apparent paradox is the tension between daydreaming and mindfulness, two apparently opposing forces that are both crucial to the creative process. "The distinction between mind wandering as the opposite of 'good' thinking is a false dichotomy," says Kaufman. "A lot of daydreaming and mind wandering—letting the mind go spontaneously where it wants to go—is very conducive to 'good' thinking, or at least it can be."

7. . . . BUT HOME IN.

Meditation and mindfulness techniques can help bring a measure of focus to your daydreaming. "Positive, constructive daydreaming is where you're thinking through an issue or doing some mental simulations of possible futures," Kaufman suggests. "That can be very productive. But what isn't productive is a type of meditation through rumination, which doesn't seem to be helpful to creativity." Meditation can help hone the mental muscle to enhance concentration, he adds, but we tend to "focus too much on the ability to concentrate on the outside world" instead of training people to plumb the depths "of their own inner world—where there's so much fertile soil for creativity."



PUSHING YOUR ENVELOPE

WHEN IT COMES TO CREATIVITY, TAKE IT TO THE LIMIT

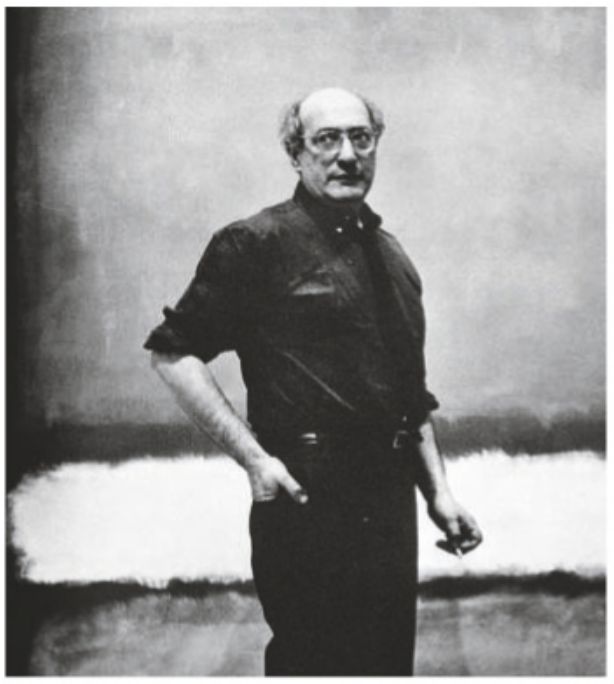
BY ROD JUDKINS

Catwalk performance art: model Shalom Harlow was splattered with paint at the Alexander McQueen show during London Fashion Week in 1998.

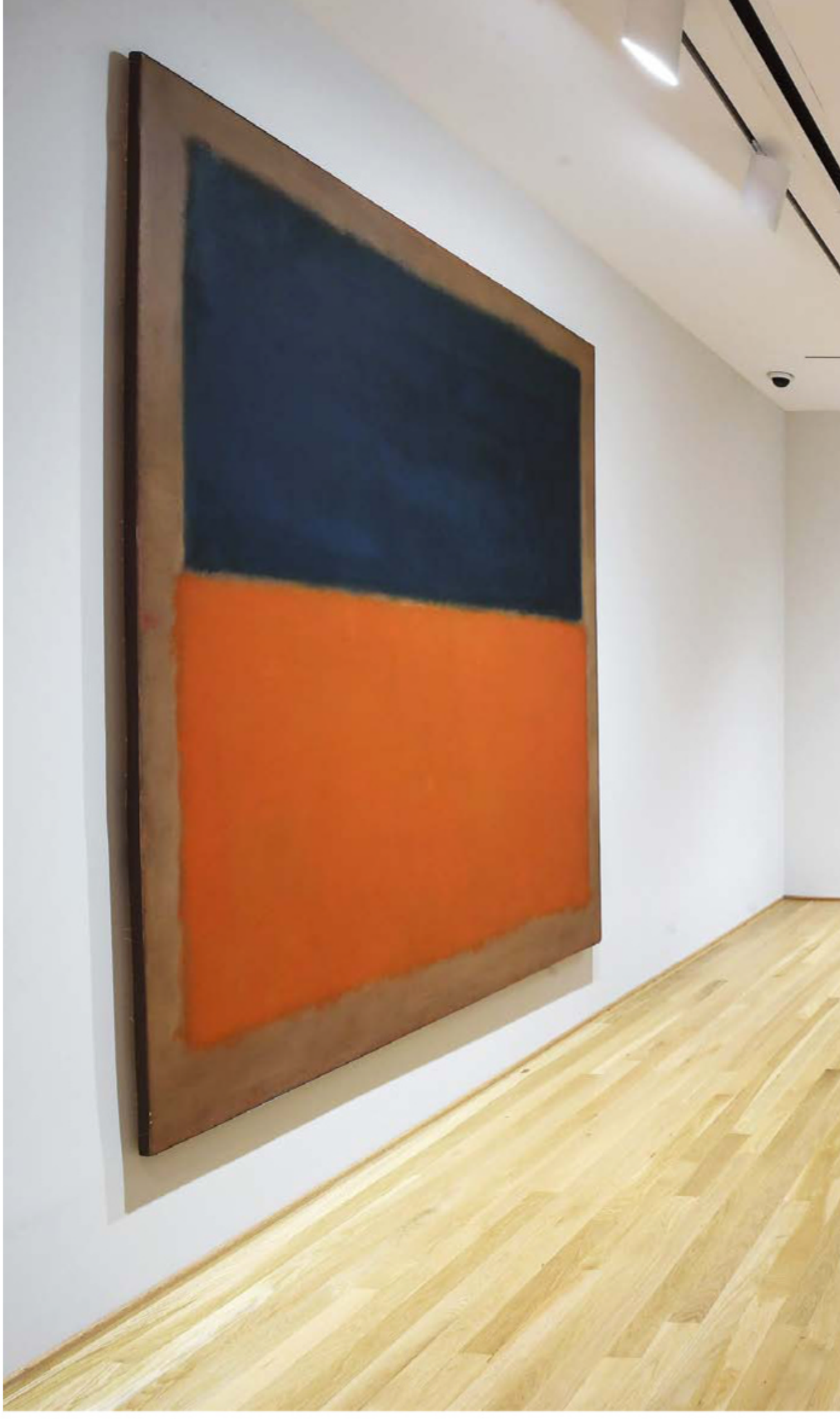
AN ELEGANT MODEL STRUTTED DOWN THE CATWALK in high heels. She wore a gracefully tailored white dress puffed out by a cotton tulle underdress. The audience contained the fashion world's most elite representatives. They were stunned when, halfway down the catwalk, the model was attacked from both sides. Colored paint was sprayed across her dress in overlapping streaks. The model's face was spattered and paint dribbled down her dress onto the floor. Why? It was all staged by the enfant terrible of fashion design, Alexander McQueen, for his spring/summer collection. The audience literally screamed their ovation, and dress No. 13, spring/summer 1999, is now a fashion icon.

It's important not to do the same old things in the same old way, but to push them to the limit and see what happens. McQueen was the most iconic and celebrated fashion designer of the 1990s. His mesmerizing outfits and otherworldly designs became instant classics—but McQueen amplified his impact by transforming fashion shows into performance art. Instead of simply marching models up and down a catwalk, McQueen's shows were sensational events, with rain pouring onto the catwalk, wolves terrorizing the audience, fire leaping from the floor, models ice-skating, models as ethereal holograms in glass pyramids, re-creations of shipwrecks and mental asylums. He turned fashion shows into unmissable events.

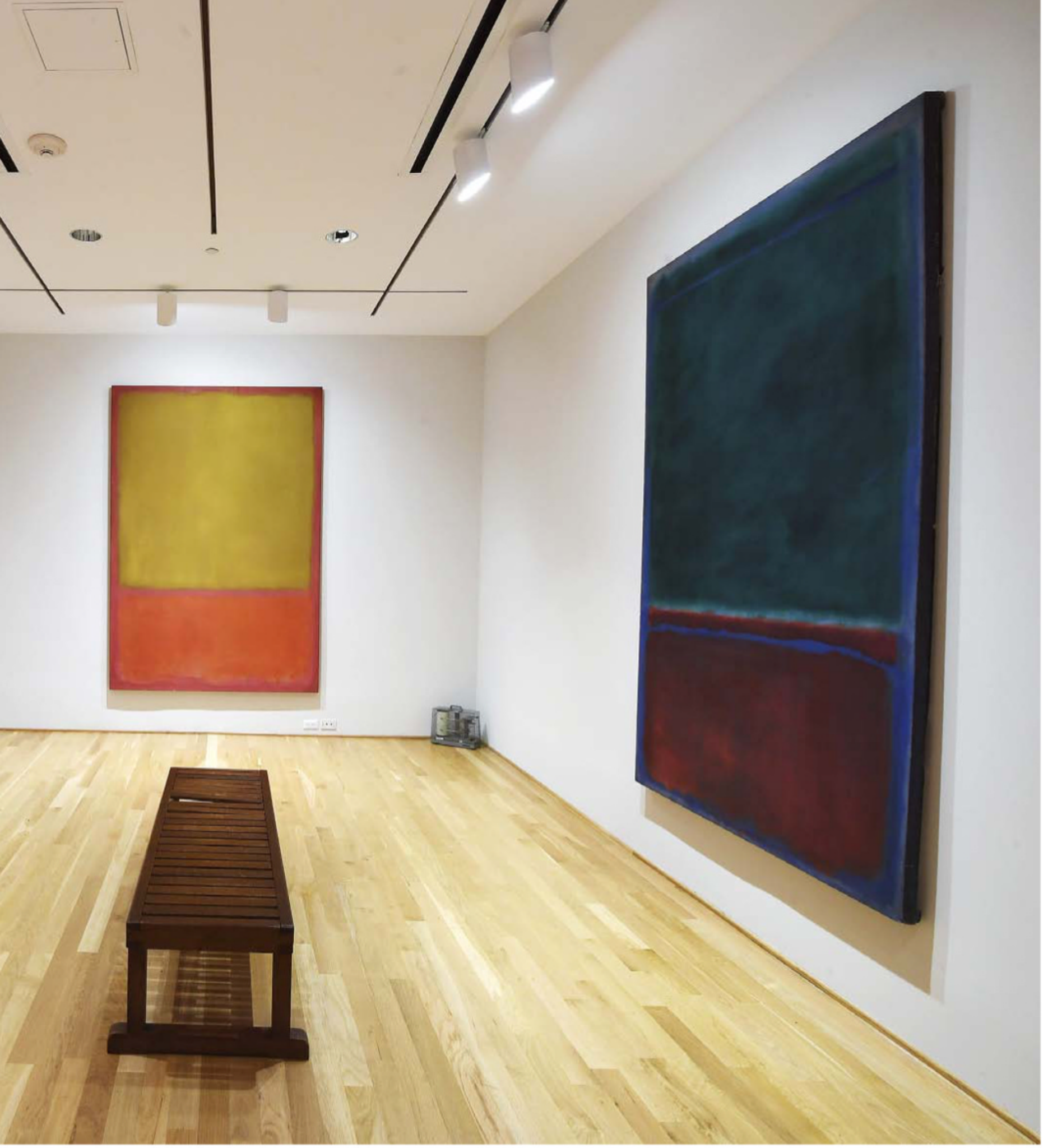
Far too many people never connect with their real talents and fail to attain their potential because they don't push what they do to excess. Creativity is like



Mark Rothko (above in 1961) started as a traditional portraitist, with works such as Folded Hands *(below). But his later abstract paintings typically featured rectangular forms bathed in color (right).*



mining; we need to dig deep to discover and uncover ourselves. One person who is willing to be excessive can achieve more in an hour than 50 reasonable people can achieve in a year. Consider the American painter Mark Rothko. His first one-man exhibition in New York featured portraits of his friends. They were ordinary. So he began to push painting to the limit. He put all his efforts into what he was good at—shape, color and composition. His paintings became more and more abstract. Eventually he and the other Abstract Expressionists started producing paintings that were entirely abstract, an expression of pure feeling and nothing more. Until then, paintings had always been based on something in the real world. Rothko developed paintings based on rectangular blocks of two to three complementary colors. The blocks vibrate and resonate against the surrounding area. The monumental canvases overwhelm and completely envelop the viewer. His paintings express basic human emotions—tragedy, ecstasy and doom. Viewers often describe feeling something close to the deep spiritual experience



Rothko claimed to have had while painting them.

Moreover, it's crucial that the creative thinker refrain from self-editing—and, to paraphrase a well-worn maxim, avoid making perfection the enemy of originality. That principle applies to business as well as the arts and sciences. The coffee chain Starbucks embraced imperfection. It introduced new concepts quickly. Whether an iced caramel macchiato or a new store design, these ideas were launched before they had been perfected and then improved as they went along. An innovation process that is trying to achieve something faultless is too slow and restricted. Innovation requires errors and failures because they lead to new ideas. The conundrum for organizations is how to foster an innovative culture, with all the messiness and faults that come with it, when the perfectionists in an organization work to reject any flaws.

Perfectionism can be a roadblock to new ideas; it is a full stop, whereas imperfection can lead somewhere unexpected. When my daughter, Scarlet, was at school, she had to produce a self-portrait for an art exam. She felt uncomfortable about it, so

she portrayed herself through frosted glass. It obscured the detail of her features but created a mysterious, blurred and intriguing image. She was worried about the response to a self-portrait that didn't clearly show her face. Her teachers loved it and so too did London's Saatchi Gallery, which later included it in an exhibition. Strive for imperfection. Miss deadlines, get lost on the way to the airport, forget to reply to emails and show up at parties a day early. It's more interesting. If it's broke, don't fix it; if it ain't broke, break it.

As constricting as perfectionism is an excessive preoccupation with utility. How many of us have come up with original ideas, then discarded them as impractical? For instance, the Juicy Salif is a lemon squeezer that doesn't work. Yet it's also a design icon and a huge commercial success. Why? The design consists of a teardrop body supported by three legs, cast from aluminum, a metal that we associate with modernity and aircraft. What makes the squeezer so distinctive and therefore so popular is that it is imbued with the personality of its creator, Philippe Starck. It brings together all of his obsessions. It's been exhibited in the Museum of Modern Art, so it's not just design, but art. Starck designed the Juicy Salif in a restaurant while eating squid. He squeezed lemon over the squid, wondered if the shape of the squid could be used as the basis for a lemon squeezer and started sketching on a napkin (now on permanent display in Milan's Alessi Museum).

As a child, Starck was fascinated by science-fiction comics and spent hours redrawing spaceships. His father was an aircraft designer, and Starck was enthralled by the sleek lines of the aluminum craft. Another of his passions was the diverse shapes of animals and plants. The result of these disparate influences, the lemon squeezer, was successful because it was personal. He didn't ask chefs and cooks to test prototypes and adapt it to their needs. He made it the way he wanted to. One of the key ingredients of the success of the Juicy Salif was that it didn't work. Its height made it unstable, lemon juice dribbled down the legs, and its feet scratched kitchen work surfaces. You might expect this to detract from its reputation, but no, it enhanced it. The public identified with the view that expression was more important than function and that it's the idea that counts. The fact that it was dysfunctional became its unique selling point.

The non-functional but sleekly designed Juicy Salif lemon squeezer (opposite) is a crowd-pleaser. Paris's Pompidou Centre (above) "turned the architecture world upside down," said one* New York Times *critic.

Perfectionism and an overemphasis on utility can be enemies of creative expression.

The genuinely innovative are led by their passions and not by rational ambitions. New ideas spring from personal interests, even if they seem irrelevant to the task at hand. Innovative people put practical considerations aside; thinking about logistics leads to thinking logically, which ties down the leaps of the mind required to create something unique. Another design icon that breaks rules of practicality is the "Well Tempered Chair," produced by Ron Arad. It makes the sitter ill-tempered because it's made from sheets of steel and is too uncomfortable to sit on. Architects Renzo Piano and Richard Rogers designed the Pompidou Centre in Paris inside out. Utilitarian features such as escalators, plumbing, air vents and electrical cables were put on the outside, freeing up space inside for exhibitions and events. The futuristic design required constant repainting, leading to spiraling maintenance costs. But it's an architectural landmark, because Piano and Rogers, like all these creative thinkers, poured their obsessions into their work and ignored the rule that "form follows function."

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DOES SCREEN TIME STUNT KIDS' CREATIVITY?

DEVICES CAN SPUR THE IMAGINATION, BUT SOME FEAR THEY MAY ALSO HAMPER DEVELOPING MINDS

BY MARK YARM

IN EARLY JANUARY 2018, TWO OUTSPOKEN APPLE INC. INVESTORS made headlines with an open letter to the tech behemoth. Barry Rosenstein of Jana Partners and Anne Sheehan of the California State Teachers' Retirement System urged Apple to respond to the "growing body of evidence" that excessive smartphone use by kids has "unintentional negative consequences." They pointed to research showing that the average American teenager who uses a smartphone got their first phone around age 10 and now spends more than 4.5 hours a day on their device—and that's *not* including talking or texting. "It would defy common sense to argue that this level of usage, by children whose brains are still developing, is not having at least some impact," the investors wrote.

To bolster their argument, Rosenstein and Sheehan cited a number of other studies, including a Canadian university survey finding that 75% of teachers said their students' ability to focus on educational tasks had decreased, chiefly due to digital technologies; alarming research from San Diego State University showing that U.S. teens who spend five hours or more a day on electronic devices are 71% more likely to have a risk factor for

Pediatrician Jenny Radesky suggests that parents should play an active role in directing and monitoring their kids' device time.

suicide than those who spend less than one hour on them; and a University of California, Los Angeles, study that found that children who had attended a device-free outdoor camp for five days outperformed a control group on tests for empathy.

None of this comes as a surprise to psychotherapist Nicholas Kardaras, who says the Apple investors' letter simply validates what he has been arguing—albeit far more forcefully—for years. Kardaras is the author of *Glow Kids: How Screen Addiction Is Hijacking Our Kids—and How to Break the Trance* (2016). He has been dismissed by some as an alarmist when it comes to children and screens—he once wrote a *New York Post* op-ed titled "It's 'Digital Heroin': How Screens Turn Kids into Psychotic Junkies"—but more recently, Kardaras says, people are coming around to his way of thinking about smartphones, tablets and other such ubiquitous devices.

"The media are finally beginning to cover some of the negative impacts of screen time," he says. "But those stories tend to focus most on screen addiction, as well as some of the other clinical impacts like ADHD effects, depression, anxiety, etc." Meanwhile, Kardaras points out, "you don't see much talk about how screens stunt children's creativity by robbing them of the opportunity to create their own interior visual imagery in the landscape of their minds." By essentially streaming intense visual imagery into the still-developing mind of a child, he says, "we stunt the neurosynaptic development of the parts of the brain devoted to creativity—that part of the brain essentially atrophies."

Indeed, irate investors Rosenstein and Sheehan do not take Apple to task over how all this screen time affects kids' creative development. And perhaps there is good reason for that: there has been a dearth of scientific research dedicated specifically to the relationship between touchscreens and creativity. "The truth is that creativity hasn't really been

studied as a child-development psychological concept since around the 1960s," says Jenny Radesky, an assistant professor of developmental behavioral pediatrics at the University of Michigan C.S. Mott Children's Hospital.

Radesky adds that research into screens is hampered by some practical concerns—it can take years to get a thorough study up and running, for instance—and the difficulty in keeping pace with the technology. (Hard to believe, but the first iPad came out just eight years ago.) So there remain lots of unknowns about the effects of screens on kids, particularly in terms of creativity—which by its very nature is difficult to define or quantify.

Still, many researchers suggest that screens get in the way of activities like daydreaming (which can stem from boredom) and unstructured outdoor play, which help children develop their creativity and imaginations. "We tend to think nothing is happening when we're daydreaming, but the brain just totally lights up in those moments because that's when it makes connections between things it didn't see as connected," sociologist Christine Carter of the University of California, Berkeley, explained in an interview with the *Deseret News*. "Technology really impacts us in that way because it basically steals all our downtime. When kids might have been playing, daydreaming or just waiting for your parents to come pick you up—that's high creativity-building time that's now taken up by our devices."

Inspired by the PBS children's series* Wild Kratts*, the Going Batty! educational app employs motion-detection technology to allow children to experience life as a bat.

On the other hand, Sara DeWitt, vice president of PBS KIDS Digital, has a far more sanguine view of screens and creativity. Last year, she gave a TED Talk titled "Three Fears About Screen Time for Kids—and Why They're Not True." DeWitt does believe there needs to be some kind of limits on screen time and plenty of parental oversight, but she also argues that when apps "inspire kids to do something else, you can do some pretty amazing stuff."

As an illustration, DeWitt points to *Wild Kratts*'s Going Batty!, a PBS KIDS educational app that utilizes a device's camera to give kids onscreen bat wings. When PBS was testing the game with children, her favorite part was what happened after they shut down the app—and the kids continued pretending to be bats.

"They kept flying around the room. They kept veering left and right to catch mosquitoes," DeWitt recalled. "And they remembered things. They remembered that bats fly at night. And they remembered that when bats sleep, they hang upside down and fold their wings in. This game definitely got kids up and moving. But also, now, when kids go outside, do they look at a bird and think, 'How does a bird fly differently than I flew when I was a bat?' The digital technology prompted embodied learning that kids can now take out into the world."

Of course, most touchscreen apps don't work this way. For her part, the University of Michigan's Radesky says she's largely unimpressed with most of the apps that are tailored for kids. "The thing that has frustrated me the most about the way a lot of children's apps are designed is that they're overstructured," she says. "They just feed [experiences] to the child, over and over again. They often have pacing that's demanding the child follow the app's pace rather than following the child's pace." Or, as early-childhood-development expert Nancy Carlsson-Paige, author of *Taking Back Childhood*, put it in a blog piece for the *Washington Post*: "What the child does is play according to someone else's rules and design. This is profoundly different from a child having an original idea to make or do something."

Even a relatively unstructured app, like the popular Minecraft—an essentially plot-free game in which players can construct cars, furniture, homes, skyscrapers and even entire cities from virtual blocks—is no substitute for building with actual blocks, according to experts.

"Minecraft can be a great game, but [kids] need to play with Lego," Catherine Steiner-Adair, a clinical psychologist and author of *The Big Disconnect:*

Protecting Childhood and Family Relationships in the Digital Age, told the *Toronto Sun*. "For children to develop their full intellectual, creative, innovative brain pathways, they need to play in the three-dimensional real world."

In 2014, Colin Kinney, a high school teacher from Northern Ireland, sounded the alarm on this issue while addressing a conference of the Association of Teachers and Lecturers in Manchester, England. "I've spoken to a number of nursery teachers who have concerns over the increasing numbers of young pupils who can swipe a screen," Kinney said, " but have little or no manipulative skills to play with building blocks."

And then there's the matter of the kind of passive entertainment touchscreen devices are so good at delivering—for example, the seemingly inexhaustible supply of YouTube videos. "I love using YouTube to show kids something they've never seen before—volcanoes erupting, the 'I Have a Dream' speech—but kids need the support of a parent to seek out those things," Radesky says. "Usually, they're just being fed the next video that a YouTube algorithm thinks they're going to enjoy, and with the patients I see in clinic, it's usually cartoons, music videos, trucks."

Radesky points to a 2011 University of Virginia study that, although not specifically about creativity, shows how such screen viewing can affect young minds. The researchers divided 60 4-year-olds into three groups: one group watched nine minutes of the fast-paced cartoon *SpongeBob SquarePants*; another watched nine minutes of a slower-paced animated PBS show called *Caillou*, about an inquisitive young boy; and the third spent nine minutes drawing with markers and crayons. Right afterward, all the children were given four tests to assess their executive function—the ability to pay attention, solve problems and control behavior—and the kids who watched *SpongeBob* scored significantly worse than the other two groups.

"The important take-home message here is that the content of viewing actually matters," pediatrician Dimitri Christakis, director of the Center for Child Health, Behavior and Development at Seattle Children's Research Institute, told CNN about the *SpongeBob* study. "Many, many parents have rules about the quantity of programming their children watch, but far fewer have restrictions on what they watch."

So what's a parent to do when it comes to kids and screens? First of all, don't freak out. "I don't want to send parents the message that they need to feel guilty about their children's tech time," Radesky says. "But I also want them to be more intentional about the way they're using [screens] together as a family so that they can monitor and help build digital literacy and savvy in their kids."

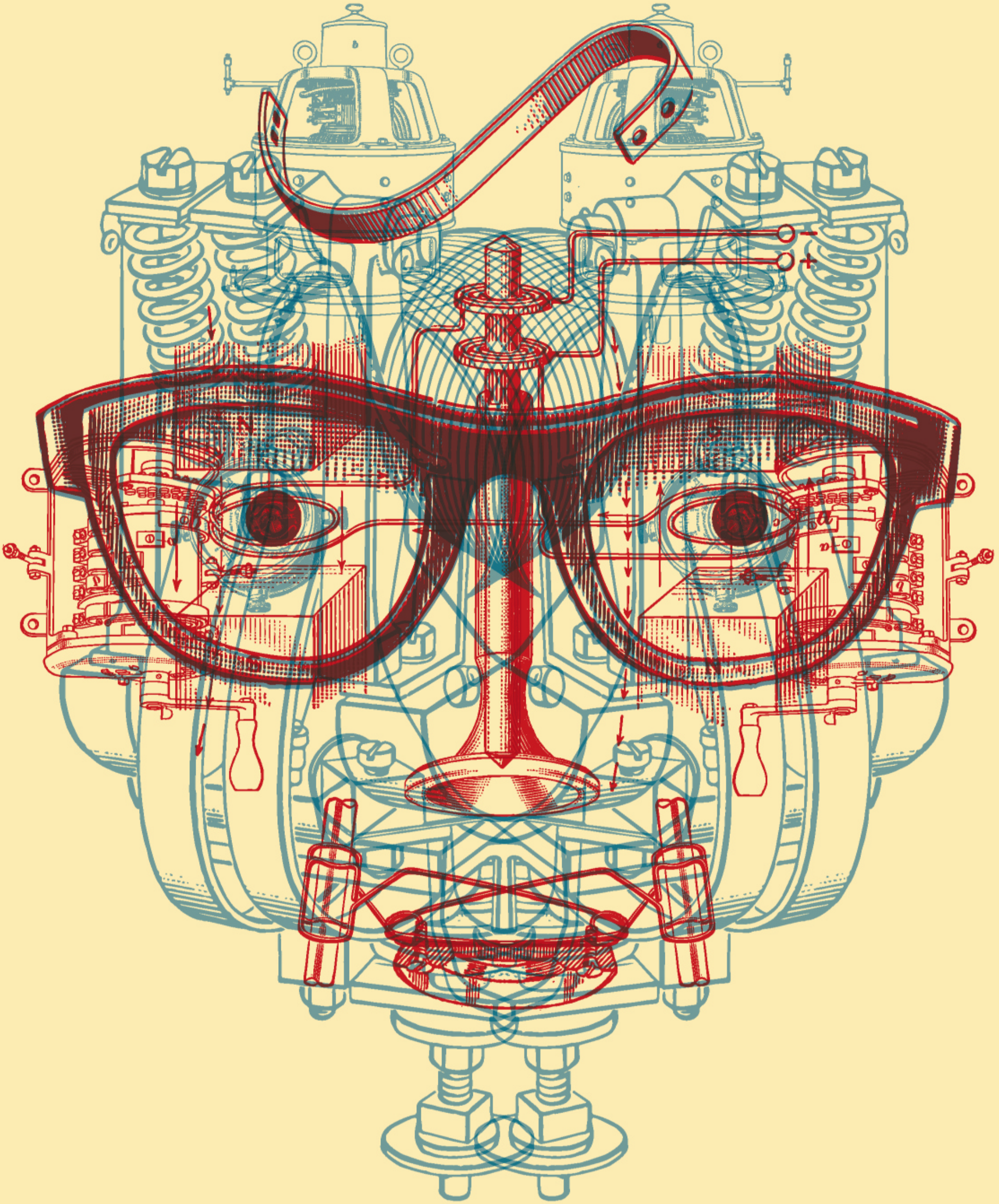
Radesky is a co–lead author of the American Academy of Pediatrics' most recent recommendations for media use, which are perhaps the most widely cited screen-time guidelines currently available. In October 2016, the AAP advised that children younger than 18 months avoid screen time altogether, save for video-chatting, and that children 18 to 24 months view high-quality programming (the academy cited Sesame Workshop and PBS as examples) with their parents, who can help the kids comprehend what they're watching. In addition, the AAP recommended a limit of one hour a day of high-quality programs for children ages 2 to 5 and imposing "consistent limits" on media use for children 6 years old and up.

Some experts stress that the quality and content of a child's screen viewing matter as much as or more than the quantity.

But perhaps, as Christakis suggests, there's too much emphasis on how many minutes or hours a day a kid is in front of a screen. So suggests Mitchel Resnick, a professor of learning research at the MIT Media Lab.

"Rather than trying to minimize screen time, I think parents and teachers should try to maximize creative time," he writes in his 2017 book *Lifelong Kindergarten: Cultivating Creativity Through Projects, Passions, Peers, and Play.* "The focus shouldn't be on which technologies children are using but rather what children are doing with them. Some uses of new technologies foster creative thinking; others restrict it."

Resnick's advice: instead of "trying to choose between high-tech, low-tech, and no-tech, parents and teachers should be searching for activities that will engage children in creative thinking and creative expression." And until there's more research available, parents and teachers will just have to rely on their gut when it comes to kids and screens and creative play.



CHAPTER FOUR

CREATIVITY AT ANY AGE

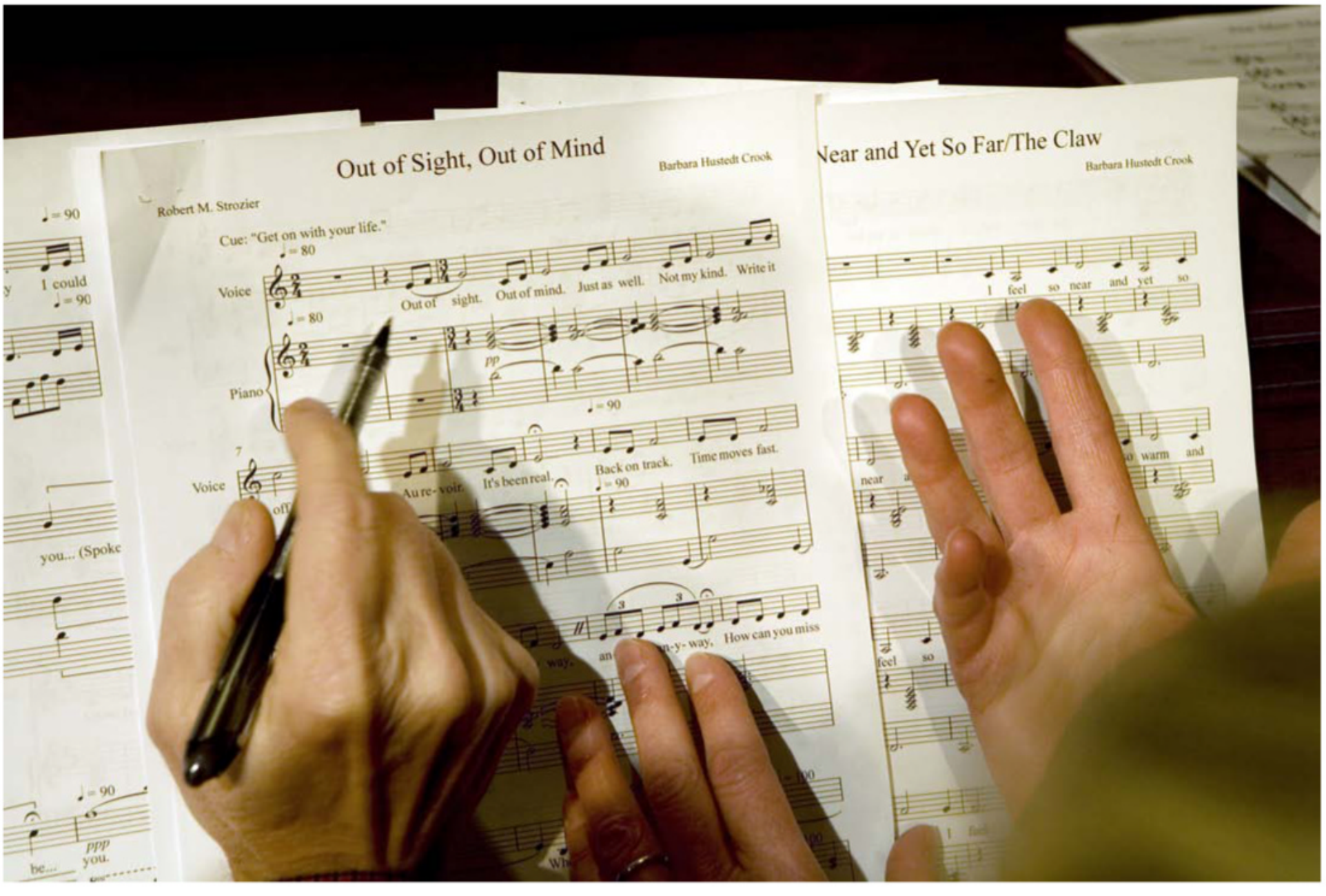
THE DRIVE CAN FLOWER AND FLOURISH FROM CHILDHOOD TO THE GOLDEN YEARS

"I draw inspiration from being outside, cycling or canoeing, from starry skies and swimming in the ocean. I also see beauty in science and mathematics, in the power of understanding and knowledge."

—Carl Wiens

Wiens, who created the image at left, is an illustrator and printmaker residing in Belleville, Ontario; he teaches illustration at Sheridan College. His work has been recognized internationally by the Society of Illustrators, American Illustration, 3 *x* 3 and Applied Arts Annual.

Late bloomers Barbara Hustedt Crook and Bob Strozier wrote their first stage musical when entering their seventh decade.



YOU'RE NEVER TOO OLD

AGING WAS THOUGHT TO HERALD CREATIVE DECLINE. BUT IN SOME WAYS THE BRAIN GROWS MORE AGILE AND EFFECTIVE OVER TIME

BY JEFFREY KLUGER

IT TOOK BARBARA HUSTEDT CROOK AN AWFULLY long time to get around to writing her first musical. She started shortly before her 60th birthday. Her friend and collaborator, Robert Strozier, waited even longer—until age 65. It's not that they didn't have the creative chops for the job. The two had spent their careers writing and editing in New York City, and Crook has a background in performing, singing and piano. But creating a musical always felt just out of reach—until it didn't.

"Somehow I have a confidence I didn't have before," says Crook. "I find that my brain makes leaps it didn't make so easily. I can hear my inner voice and trust instincts and hunches in ways I didn't used to."

And, says Strozier, they're both a lot more willing to take chances than in the past. "At a certain age," he says, "you either get older or you get younger. If you get younger, you venture out and take risks."

Risk-taking seniors making daring mental leaps? That's not the stereotype. Indeed, until quite recently most researchers believed the human brain followed a fairly predictable developmental arc. It started out protean, gained shape and intellectual muscle as it matured, and reached its peak of power and nimbleness by age 40. After that, the brain began a slow decline, clouding up little by little until, by age 70 or 80, it had lost much of its ability to retain new information and was fumbling with what it had. But that was all right because late-life crankiness had by then made us largely resistant to new ideas anyway.

That, as it turns out, is hooey. More and more, neurologists and psychologists are coming to the conclusion that the brain at midlife—a period increasingly defined as the years from 35 to 65 and even beyond—is much more elastic and supple than anyone ever realized. Far from slowly powering down, the brain as it ages brings new cognitive systems online and cross-indexes existing ones in ways it never did before. You may not pack so much raw data into memory as you could when you were cramming for college finals, and your short-term recall may not be what it was, but you manage information and parse meanings that were entirely beyond you when you were younger. What's more, your temperament changes to suit those new skills, growing more comfortable with ambiguity and less susceptible to frustration or irritation. Although inflexibility, confusion and even later-life dementia are very real problems, for many people the aging process not only does not batter the brain; it actually makes it better. Small wonder the likes of Matisse, Georgia O'Keeffe and Doris Lessing remained productive well past 70.

"In midlife, you're beginning to maximize the ability to use the entirety of the information in your brain on an everyday, ongoing, second-to-second basis," said George Bartzokis, the celebrated UCLA neurologist who died in 2014. "Biologically, that's what wisdom is."

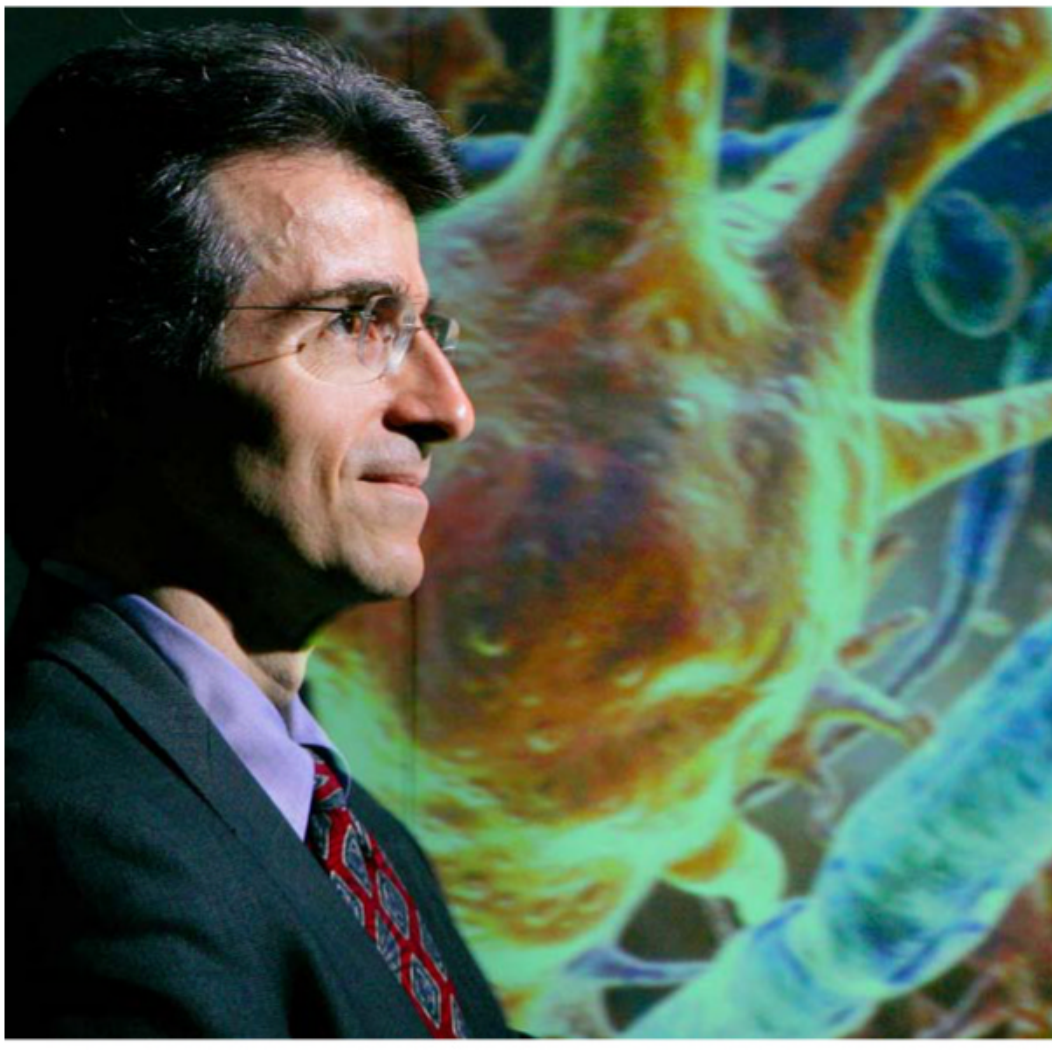
If your mind does indeed grow more agile as you age, one of the things that may help it do so is the amount of glue you carry around in your brain—*glia* (Greek for glue) being what the 19th-century German anatomists called it. Only about half the mass of the brain is composed of gray matter, or nerve cells; the rest is white matter, the connecting tissue that, in a sense, glues it all together. Much of that white matter is made of conductive nerve strands, and covering each fine wire is a fatty sheath of myelin that keeps nerve signals from sputtering out or cross-firing during transmission.

Throughout our lives, fresh layers of myelin sheathing are laid down in the brain. In infants and children, who grow increasingly coordinated as they mature, the bulk of that process takes place in the

motor and sensory lobes. If we acquire better reasoning skills in middle age, it would follow that most of the myelin added in those years would appear around the signal-transmitting axons in higher brain regions that are the seat of sophisticated thought. Essentially, the brain spends decades upgrading itself from a dial-up internet to a high-speed version, not fully completing the job until age 45 or so.

To test that idea, Bartzokis once used magnetic resonance imaging to study the volume and distribution of white matter in 300 healthy subjects from 18 to 75 years old, as well as in hundreds of older people suffering from such brain-related ills as Alzheimer's and Parkinson's diseases. As he suspected, the healthy adults had the most myelin in the frontal and temporal lobes—where big thoughts live. The quantity of sheathing reached its peak around 45 or 50, exceeding the amount in unhealthy older subjects and healthy younger ones.

"This last little bit of myelination essentially puts us online," Bartzokis told TIME after he had completed the work. "You may not have the same amount of information you had when you were 20, but you can use it better in everyday life."



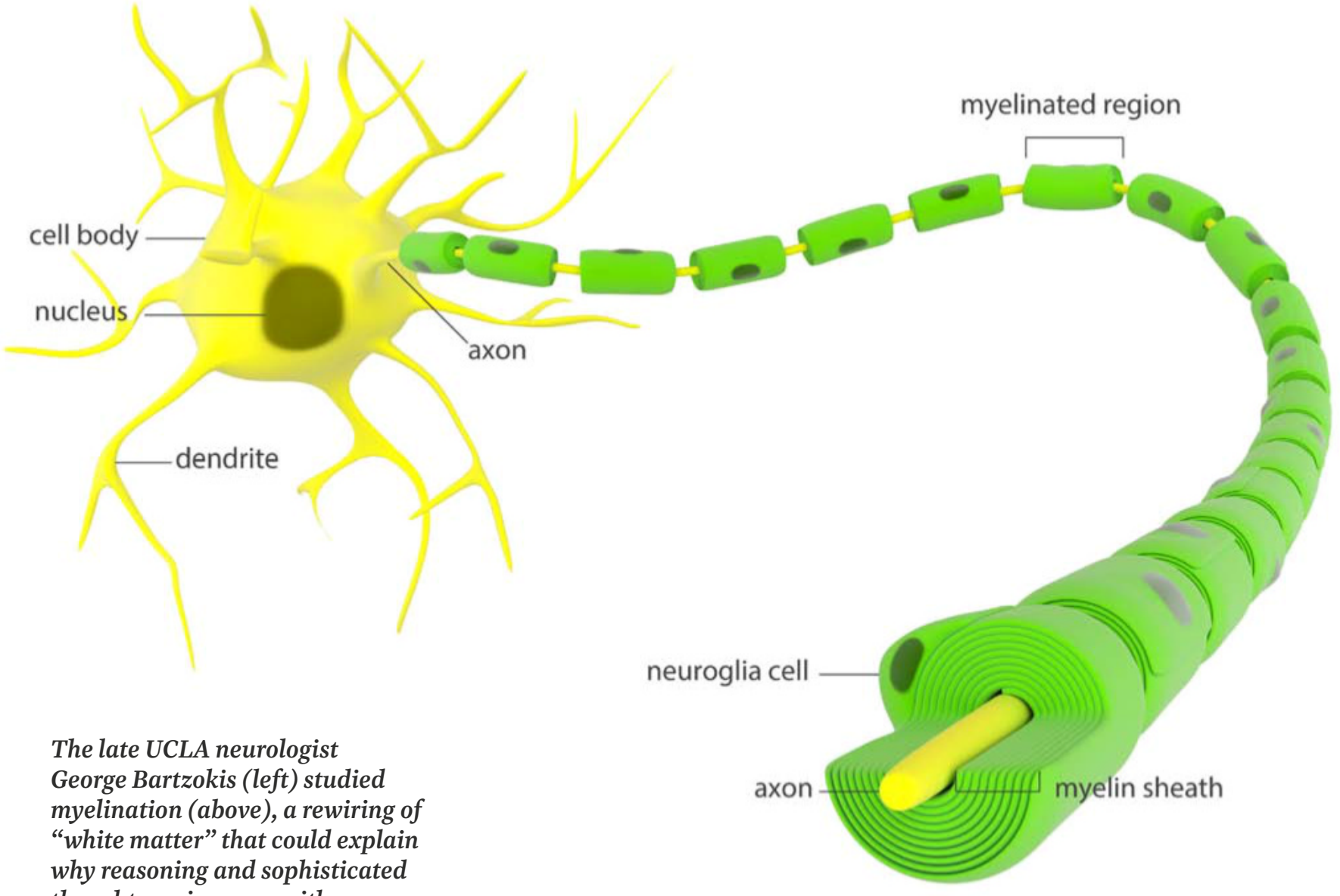
It's not just the wiring that charges up the brain as we age; it's the way different regions start pulling together to make the whole organ work better than the sum of its parts. For all its plasticity, the brain is a specialized machine, with specific regions handling specific operations. The greatest divergence comes between the left and right hemispheres, which often work almost independently of each other. That is not such a bad thing, because one hemisphere can be busy writing a grocery list or solving an equation while the other scans the environment and tends to other basic chores.

As we age, however, the walls between the hemispheres seem to fall, with the two halves working increasingly in tandem. Neuroscientist Roberto Cabeza of Duke University dubs that the HAROLD (hemispheric asymmetry reduction in older adults) model, and judging by his work, the phenomenon is a powerful one. Cabeza recruited a sample group of adults 65 to 95 years old who had scored high on a memory test, along with a group of lower-performing adults of the same age and a group of younger, college-age adults. He then asked them all to perform a series of tasks that called on numerous skills, including language, memory, perception and motor functions. Throughout the tasks, he conducted functional magnetic resonance imaging scans of their brains. Again and again, he found that the high-functioning older adults were using either a hemisphere different from the one the other subjects were using or both hemispheres at the same time.

Why that is so is still unclear, but Cabeza doesn't believe the brain is programmed to get stronger as it ages. Rather, he acknowledges, in many ways it gets weaker, with neurons processing information less efficiently. The bilateralization may be a trick the brain uses to compensate for the decline, sometimes integrating the hemispheres so efficiently that our thought and reasoning processes are actually better than they were before.

"It's similar to the way you need both hands to lift a weight that you could lift with one hand when you were younger," Cabeza says. "In the brain, there's a nice, natural distribution of resources. You get more neural tissue to support the task."

As the brain's flexibility improves, so too may the temperament we bring to our work. There's no question that personalities can calcify with age, causing us to become less receptive to new experiences and flat-out crabby when faced with them. But that's not the case with everyone. In fact, in many people the opposite happens.



The late UCLA neurologist George Bartzokis (left) studied myelination (above), a rewiring of "white matter" that could explain why reasoning and sophisticated thought can improve with age.

In 1958 psychologist Ravenna Helson, now a professor emeritus at the University of California, Berkeley, began a long-term study of 142 women, all of them 21 years old, at Mills College in Oakland, Calif. She interviewed the subjects and took measures of their personalities, drives, relationship skills and the like. Then she reinterviewed them at ages 27, 43, 52, 61 and 70 to determine how those traits changed over time. When she and then–graduate student Christopher Soto—now an associate professor of psychology at Colby College in Maine—collated the data from the 123 women who stuck with the study, the results were surprising.

On the whole, they found, the women's highest scores in inductive reasoning occurred from their 40s to their early 60s. Similarly, their so-called affect optimization (the ability to highlight the better aspects of one's personality and restrain the less attractive ones) and their affect complexity (the ability to evaluate various contradictory ideas and remain objective) did not peak until their 50s or 60s. There was also an increased tolerance for ambiguity and an improved ability to manage relationships.

The Mills sample group was hardly random, consisting principally of white women of the same age who attended the same college. Still, they were 123 different individuals, yet the results were uniform. "People generally describe personality change in middle age as a midlife crisis, with all its negative connotations," says Soto. "In the Mills women, the change was positive—a reorienting, not a crisis."

If such a change occurs, says Berkeley psychologist Robert Levenson, it may be shaped in part by evolutionary forces. Humans' comparatively long life spans and extended families are very good things, but keeping big broods healthy and well behaved over the decades takes more than the energy of young parents. It takes the cool heads and wise counsel of the family graybeards too. "Evolution isn't just about reproduction," Levenson says. "When you get into your 40s and 50s, you're caretaking, looking after your children, grandchildren, even the people who work for you. There's an advantage to having a more relativistic mind."

It's that talent for reflective thinking that explains the role older adults have always played in the human culture. Not for nothing are history's firebrands and ideologues typically young, while judges and peacemakers and great theologians tend to be older. Not everyone achieves the sharp thought and serenity that can come with age. But for those who do, the later years can be the best they've ever had.

WHEN SCHOOLS GET CREATIVE

DESPITE OBSTACLES—LARGE CLASS SIZES AND AN EMPHASIS ON STANDARDIZED TESTS—SOME TEACHERS ARE NURTURING PURE IMAGINATION

BY KATIE REILLY

FOR ISMET MAMNOON, THE STUDY OF CREATIVITY has been a "life-altering" family affair, affecting everything from how she schedules her time to how her family makes decisions about their home to how she communicates with her daughters. Mamnoon was an accountant and a 39-year-old mother of two when she returned to school in 2009 to earn a master's degree in creative studies at SUNY-Buffalo. It changed how she thought about the world, she says, "like someone had turned on a light in a part of my brain that I hadn't even known was in darkness."

Mamnoon has since attended annual creativity conferences with her family; inspired her husband, a physician, to take an introductory creativity course; and built a career around teaching the creative process to other parents, business leaders and educators in countries around the world.

She is one of many people now arguing that creative thinking is more important than ever before. And although some education experts have long advocated for the introduction of creativity into the classroom, they say more people now seem to be heeding that advice.

Gerard Puccio, chairman of the International Center for Studies in Creativity at SUNY-Buffalo, says it's never been easier than it is now to persuade academics and students that creativity is essential. "There's never been a time in my life when it's been in greater demand," says Puccio, who has spent nearly 40 years working in the field of creativity. SUNY-Buffalo now has about 100 graduate students enrolled in its creative-studies program — roughly five times as many as it did in 2000.

Many K-12 schools and universities across the country are experimenting with innovative teaching methods to foster greater creativity in their students, motivated by global competition and the realities of the ever-changing workforce into which

students will graduate. But such initiatives can be hindered by large class sizes, an emphasis on standardized testing and curricular demands that limit teachers' free time and flexibility.

"I just see it as a perfect storm," Puccio says. "Here you have the world demanding creativity skills, but education, in some ways, has moved in the opposite direction, with a focus on standardization and making every kid the same, versus allowing their creative potentials to flourish."

The average U.S. public-school student takes 112 mandatory standardized tests between prekindergarten and their high school graduation, according to a 2015 report by the Council of the Great City Schools. And a 1995 study by researchers at Union and Skidmore colleges found that although teachers often say they enjoy having creative students in class, they tend to respond negatively to character traits associated with creativity—such as impulsiveness and nonconformity—making school a generally inhospitable environment for it.

Meanwhile, studies show that creativity can boost happiness and well-being and is increasingly necessary for 21st-century success. A 2016 report by the World Economic Forum predicted that the top

MIT Media Lab's Lifelong Kindergarten (top) holds a workshop using Scratch, which allows students to program interactive stories, games and animations. Mitchel Resnick (bottom) runs the group.

three job skills in 2020 will be complex problem-solving, critical thinking and creativity, noting that although artificial intelligence will continue to disrupt the workforce and replace certain jobs, creativity is a uniquely human advantage.

That pace of technological change has raised questions about the role of education: Are classes in which teachers simply distribute information and encourage rote memorization useful in a world where students have Google at their fingertips? Puccio and other creativity experts would say no, arguing that education should focus more on teaching students higher-order creative-thinking skills. They have sought to dispel stubborn myths about creativity: it's widely considered a rare natural ability that emerges in a momentary flash of brilliance, often in the arts, but experts say creativity is actually a structured process that can be applied in areas of study and work outside the arts. And because it's a process, rather than a spontaneous stroke of genius, they're calling for creativity to be taught to students from kindergarten to graduate school in order to adequately prepare them for the future.

Some creativity advocates call for a radical overhaul of the educational system; others suggest working within existing structures.

FOR THE PAST YEAR, JENNIFER Isernhagen's children did not bring their books or backpacks to school on Wednesdays—a day when there was no homework at New Jersey's Primoris Academy, because there were no core classes on those days. Instead, students spent that day rotating through interdisciplinary courses of their choosing, ranging from musical theater and architecture to robotics and app development. "My daughter's taking martial arts—I would not have seen that one coming," Isernhagen says. "She did that on her own."

"I would love, as a parent, to have some input, but I also really like that they have the autonomy to choose," she adds. "There are so few opportunities for children to have control and be assertive about their learning."

Primoris Academy—a private school where tuition ranges from $14,500 in elementary school to $24,500 in high school—has sought to make creativity a core tenet of its curriculum, grouping students by ability rather than age, emphasizing hands-on learning activities and giving freedom to teachers to experiment with their lesson plans. "We encourage failure and then revision, and we give a lot of open-ended tasks," says Cara Ruggiero, the school's dean of instruction, noting that the school aims to get students working together as much as possible. "It's definitely much louder, and a bit more messy."

In Keith Sawyer's creativity classes at the University of North Carolina at Chapel Hill, he assigns a variety of projects to his students—design a typeface, program a robot, produce a music track—but introduces speed bumps and new requirements each week, forcing students to rethink their plan and making it impossible for them to get it right the first time.

"I think if we really want kids to develop as creative thinkers, we need to make the rest of school—in fact, the rest of life—more like kindergarten," says Mitchel Resnick, who leads the Lifelong Kindergarten group at the MIT Media Lab to develop new technologies for creative learning. He says all stages of education should allow more time for students to work collaboratively on interdisciplinary projects that pique their interests. "Learning a fixed set of facts during your schooling is not going to provide very well for your whole life, since the world keeps changing," he says.

Some creativity advocates call for a radical overhaul of the educational system, from classroom design to curriculum requirements. But others suggest that the solution, especially in the short term, is to work within the current system while making creativity a deliberate part of every lesson, no matter the discipline.

"I think we need to get over the idea that creativity can't operate in these constraints," says Ronald Beghetto, a professor of educational psychology at the University of Connecticut who has written about creativity in the Common Core classroom. "I think it's just about rethinking the curriculum and rethinking the time we have."

Beghetto says it's important to introduce real-world applications into as many lessons as possible. Teach students about perimeter by asking them to design a rooftop garden benefiting the local community, for example, or teach them about photosynthesis by growing vegetables for a nearby

Students work on architecture projects at New Jersey's Primoris Academy, a private school that encourages hands-on creative activities.

food bank or soup kitchen.

He thinks education should leave room for more uncertainty and more student-led discovery. Ask students how many different ways they could possibly solve a particular math problem, he says, or ask them to list all the questions they have about a particular unit before launching into a detailed lecture.

His 12-year-old daughter, Olivia—who once complained that elementary school was a "worksheet factory"—has wondered why her teachers often ask questions for which they already have a specific right answer. "A lot of times we, as educators, over-plan students' learning experiences," he says. "I think we send the message that 'OK, nothing is welcome in this space other than what I already expect.'"

Certain degree programs and schools have started to champion innovation, but the U.S. educational system has yet to make fostering creativity a broader priority. And experts worry that the United States will soon start to trail other countries in innovation.

Mamnoon, the former SUNY-Buffalo creativity student, has traveled around the world since 2010 to lead creativity workshops for educators in China, Chile, Canada, Mozambique, Jordan and Colombia. But she was asked to run a workshop for educators in the U.S. for the first time only last year, when she led training for teachers at a New York elementary school.

Professors say part of the problem is that innovative learning techniques are resource-intensive. It's expensive to use cutting-edge technology and to redesign classrooms for movable desks and whiteboards. By comparison, lectures foster less creativity but are economically practical.

Part of the problem is also that, from the top down, the U.S. educational system is not designed to incentivize creativity, as schools are tasked with meeting certain testing standards and colleges still prioritize SAT and ACT scores in admissions.

Robert Sternberg, a Cornell University professor and former administrator at Tufts and Oklahoma

Keith Sawyer conducts his creativity class at the University of North Carolina. He likes to change up expectations so students have to think on their feet.

State, advocates incorporating creative criteria into the admissions process, asking applicants to design a science experiment, complete an unusual writing prompt or submit a drawing. The process, when applied, changed whom the schools admitted, finding strong applicants who might otherwise have been overlooked because of lower SAT scores.

But Sternberg said it is difficult to change the long-term status quo at universities, where administrators are beholden to many constituencies, including alumni, donors and lucrative athletics. "The creative-kid constituency is not a powerful one," he says. "They're not necessarily the kids who are going to get the highest grades, because grade-getting isn't what they specialize in. They're not necessarily rich, they're not necessarily politically powerful . . . They don't have anyone going to bat for them."

Sternberg says it's bad for higher education and society at large if most students at universities are content to play within the existing system and lack the skills to challenge it. "You get a lot of kids who are smart, but they're smart in the way of 'Tell me what to do and I'll do it really well.' You give them a structure, and they'll work within the structure," he says. What the world actually needs, he suggests, are "the kids who can create the structure."

In 2006, Sir Ken Robinson, a creativity expert and education adviser, gave what remains the most popular TED talk of all time—asking whether schools are killing creativity. Robinson thinks that question is still relevant today, but he's optimistic about what the future of education looks like.

"There is boundless energy among teachers, and I'm excited by the fact that more and more people are looking for alternatives, and that's the insurgent energy that we should be tapping into," he says. "If you give people permission to do it, if you say it's OK to try this, and if you remove some of the penalties for innovation, my experience has always been that people rise to the challenge."

HOW PARENTS CAN EXCITE AND INSPIRE

SOME DOS AND DON'TS FOR MOMS AND DADS WHO WANT TO STOKE—NOT STIFLE—THEIR KIDS' CREATIVE IMPULSES

BY SARAH BEGLEY

WHETHER IT'S EXPRESSED WITH WATER PAINTS OR widgets, most parents hope their children will display some level of creativity. The challenge is how to foster it. Cultivating a child's creative side can reap rich, long-term rewards—studies show that it correlates with greater professional success later in life, whether or not the individual goes into a field you might typically think of as "creative." Beginning in the late 1950s, psychologist E. Paul Torrance assessed 400 children with a survey that measures creativity in much the same way that an IQ test gauges intelligence. Following the children through their careers, he found that those with higher creativity scores racked up far more books published, artworks exhibited, songs composed—as well as ad campaigns executed, research papers published, patents filed and lectures given. In fact, the correlation between childhood creativity and adult accomplishment was three times as strong as that between childhood IQ and adult accomplishment.

Studies show that when children read imaginatively stimulating books—such as* A Wrinkle in Time*—the activity correlates to greater creativity later in life.

In any discipline, creativity is all about generating unique, innovative ideas. Adam Grant, a professor at the Wharton School of Business and the author of *Originals: How Nonconformists Move the World*, puts gifted children and creative children in different categories. "Being gifted is usually about raw intelligence," he says. "Gifted kids tend to be really precocious, so they tend to do things like learn a second language before they're 5 and play Mozart when they're 7 and become chess grand masters in their teenage years. It's really easy to marvel at that and say, 'Wow, these kids are brilliant, and they're gonna change the world!'"

But that global transformation rarely follows. "I think the reason for that is, as I like to put it, practice makes perfect but it doesn't make new," Grant

Children should be allowed "alone time," when they're free to explore the world around them.

says. "It's one thing to be able to master something that's already known or understood—to learn the rules of chess, to learn to repeat a Mozart melody with perfect precision. It's a whole other thing to be able to write your own melody or invent your own board game. At minimum, those skills are separate, but in the worst case, one may hurt the other."

Granted, certain kids may seem naturally more imaginative and inventive, but every child has some reservoir of creativity. Here are a few steps parents can take to help tap into that supply and encourage original thinking.

A high score on intelligence tests and an ability to regurgitate facts aren't necessarily predictors of creativity.

Make reading a ritual

READING, OF COURSE, IS CRITICALLY IMPORTANT TO building a child's intelligence, and a certain amount of it is key for boosting creativity as well. "There's a critical level of literacy that you need to reach in order to be creative in most fields, because if you don't have the basic ability to read, it's almost impossible to accumulate knowledge," says Grant. "For the most part, people get creative ideas from reading."

What's more, certain children's books can actually encourage more creative thinking. "There was this weird finding that you could predict patent rates 20 to 40 years later by looking at what children's books are popular in a given era," Grant says. "If we wanted to know how many patents we would generate in the U.S. today, we should go back to the 1980s and '90s and look at the children's books that were dominant. The dominant children's books that predicted spikes in patent rates were books that emphasized unique accomplishment"—think the *Chronicles of Narnia* series and *A Wrinkle in Time*. Nowadays, *Harry Potter* books may help your child more than you think.

Let freedom ring

ANN HULBERT, AUTHOR OF *OFF THE CHARTS: THE HIDDEN LIVES AND LESSONS OF AMERICAN CHILD PRODIGIES*, has studied children in history who demonstrated remarkable creative powers at a young age—some of whom went on to have highly productive adult careers. She found it was often helpful to give children

But it's also crucial that kids create in a collaborative setting, to brainstorm and exchange ideas.

the freedom to pursue their interests in their own ways, even if seemingly unorthodox. Take the case of Henry Cowell (1897–1965), a trailblazing composer. "In his childhood, though he did play the violin, he actually never practiced very hard—because he was a little bit ill, his mother didn't push him to do it," Hulbert says. But he practiced in his own unique way. When all the other children in the neighborhood would go inside to play their instruments from 4 to 5 p.m., he too would go inside to practice—inside his head. As he later wrote: "For one hour every day . . . I sat down at the desk and practiced listening to sounds in my mind. I did this very methodically." So, your child may seem to be staring off into space, but he or she could be silently composing a sonata.

That said, it is "surprising how much [the ability to perform] disciplined work as a young person can also be an ingredient to a very productive and creative later life," Hulbert says. Ideally, much of that discipline will come from within. "My sense is that conveying to a child a sense of autonomy, and a feeling that what they were doing was something they chose and they wanted to pursue, does correlate with happy productivity and exploration."

Thus with freedom comes independence—a critical element, according to Julia Cameron, author of *The Artist's Way for Parents: Raising Creative Children*. "It's very important that they have a time during the day when they are free to play according to their own delights," she says. It's also important that parents model their own independence too. This will allow the child to separate in a healthy and productive way. "Parents [must] not give children the impression that they will always be directly on tap," she says. "Instead, it's a question of, 'Not now; Mommy's working.' And then the child learns by that to set a boundary. So it becomes, 'Not now; I'm playing!' "

Encourage group creativity

WE TEND TO THINK OF CREATIVE GENIUSES AS VERsions of Archimedes, sitting in his tub and crying "Eureka!" But in many cases—and particularly in the world of the future—creative thinkers need to focus not just on solo breakthroughs but also on fruitful collaborations. "Creativity means so many different things, it's so hard to measure, it's hard to quantify in its origins and its development," says Hulbert. "But I do think that conveying to a child that they aren't individual geniuses, necessarily, is certainly a useful thing to do when so much about being a contribu-

tor to innovative and creative things now involves being able to work with other people. That's something that maybe wasn't as true in the 19th century."

"We know collaboration has a big role to play in creativity," notes Grant. "We know people working solo have a limited range of ideas. You need access to different perspectives to plant the seeds of creative insights in a lot of cases. And even if you can dream up a brilliant idea all on your own, very often it takes more than one person to execute it." Parents can encourage kids to brainstorm and collaborate with their siblings if they have them—but much peer collaboration will happen in the classroom. [See page 82.]

What not to do

IF CREATIVITY IS THE END GOAL, PRESSURING YOUR kid to get straight A's probably isn't the best strategy. Great grades as a child don't necessarily make for creative thinking as an adult—in fact, it could be quite the opposite. "Highly creative kids tend to have spikier grades," Grant says. "What you see is, in subjects that interest them, they excel and shine, but in areas that don't interest them, they tend to underperform. There's sort of this attitude of, 'I don't think this is very interesting—why should I have to study it just because my teacher told me to?' I think some of that is nonconformity and resistance to social pressure, which you see early on in creative kids."

It's also important for parents not to push their children to specialize in a particular interest too early. "I was just stunned by this research on Nobel Prize–winning scientists," says Grant. "When you compare them to their technically skilled but less creative peers, who haven't generated a breakthrough revolutionary idea, the Nobel Prize–winning scientists were significantly more likely to have artistic hobbies. So they were twice as likely to play musical instruments, seven times as likely to draw or paint, 12 times as likely to do creative writing, like fiction or poetry, and 22 times as likely to perform as actors, dancers or, yes, magicians."

Hulbert's child prodigies who went on to have successful careers also often avoided a narrow focus. In the case of math genius Norbert Wiener (1894–1964), who went on to become the father of cybernetics, she says, "Fierce though his father was about drilling him in math and drilling him in the languages he was learning, he was also himself a kind

Imposing some discipline is always necessary, but it's creatively stifling to overburden children with rules—and crucial to allow free time for play.

of autodidact with a wide array of interests." In addition to his math studies, Wiener got a college student to teach him chemistry, read books on myriad subjects and had a passion for mushrooming that took him around the countryside. "I think he himself would credit this notion that there were many different fields he was curious in, and they did spark insights. I would extrapolate that as a lesson for other parents—the more different interests that a child expresses and you can fuel and feed, the better."

Also: avoid an abundance of rules. "What happens when you have too many rules is kids learn to follow the lead of authority figures, as opposed to thinking for themselves," Grant says. "That's not to say that rules are an inherently bad thing, but when you see parents who have raised highly creative children, in the data, they tend to have fewer rules, but when they do have rules, they're more like values and principles."

Moreover, parents shouldn't try to shield their children from grown-up arguments. That's not to say full-on fighting in front of your kids is a good idea, but airing intellectual disagreements at the dinner table can be hugely beneficial. According to research, creative adults are more likely to come from homes where parents had "genuine disagreements and debates," Grant says. "When parents never disagree, or when they disagree only behind closed doors, you end up raising children who believe that their job is to figure out what their parents want and then do it. Whereas when you see your parents disagree, you can't just look to authorities for guidelines—you actually have to think for yourself."

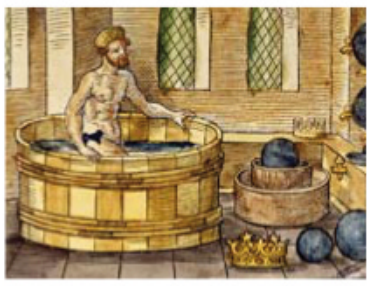
Stoke curiosity

ABOVE ALL, MAKE SURE YOUR KIDS KEEP SEARCHing for exciting new pursuits. "Creative kids tend to be fueled really heavily by intrinsic motivation and their own interest and passion and curiosity," says Grant. "If your kid hasn't developed a passion yet, what you want to do is nurture curiosity. Teaching curiosity is teaching kids to wonder about things that they may not have wondered about before and to ask open-ended questions. When they're curious, they're more likely to discover things that interest them." And once they're intrigued, there's no telling where their passions will lead them.

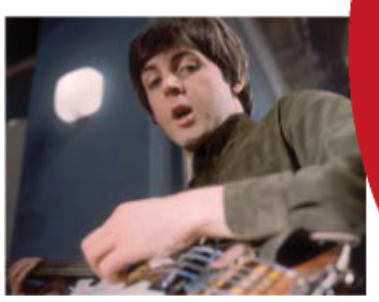
EUREKA MOMENTS

SOMETIMES INSPIRATION STRIKES WHEN YOU LEAST EXPECT IT

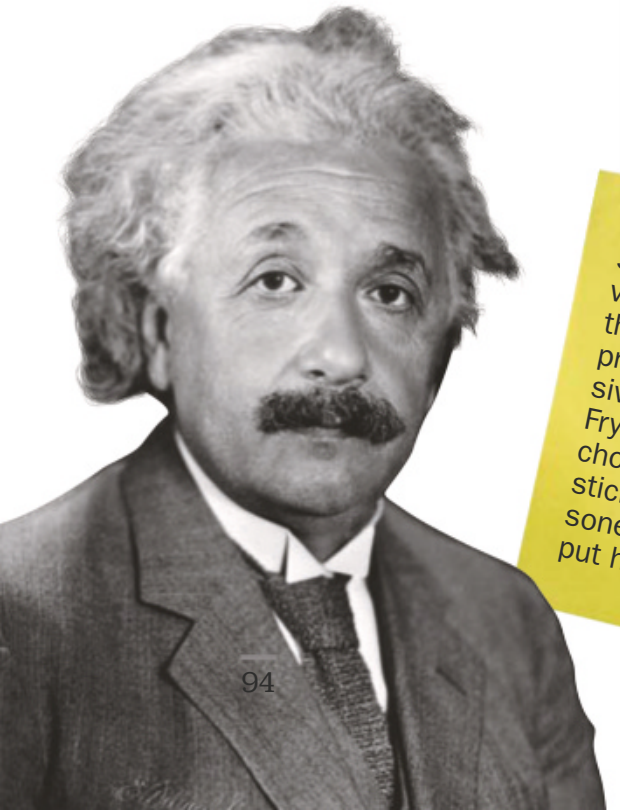
First Eureka Moment
Legend has it Archimedes was about to bathe when he discovered that an object's buoyancy force equals the weight of the fluid it displaces. Thrilled, he ran naked through Syracuse shouting, "Eureka!"



The Beatles' "Yesterday"
According to biographers, Paul McCartney composed this melody in a dream at the Wimpole Street home of then-girlfriend Jane Asher. Upon waking, he rushed to a piano and played the tune to avoid forgetting it.



Einstein's Theory
Riding a streetcar in Bern, Switzerland, the physicist was struck by the sight of the city's medieval clock tower—and was inspired to devise his elegant special theory of relativity: time can beat at different rates throughout the universe, depending on how fast you move.



Band-Aid
Thank Josephine Knight Dickson for those ubiquitous adhesive bandages. She often cut and burned herself while cooking, which in 1920 prompted her husband, Earle, a Johnson and Johnson cotton buyer, and Thomas Anderson to develop a prototype so Josephine could dress her wounds—unaided.

Invention of TV
At 14, Philo Farnsworth was plowing a potato field when he suddenly realized how television could work. The back-and-forth motion of the till inspired him to imagine how an electron beam could scan images line by line—the basis for almost all TVs until LCD and plasma screens.

Post-it
3M scientist Spencer Silver just couldn't interest the company in his low-tack, pressure-sensitive adhesive. Then colleague Arthur Fry found an application—at choir practice. Coating the sticky stuff on paper, Fry reasoned, he could create stay-put hymnal bookmarks.

GoPro
GoPro visionary Nick Woodman dreamed up his wrist-strap-mounted, 35-millimeter camera while trying to capture his passion—surfing—on film. He turned it into a business that, at its height, was worth $11 billion.

Microwave
The quickie oven was born while engineer Percy Spencer was working on magnetrons for military radar sets. When a candy bar in his pocket melted near some radar, Spencer realized microwaves could penetrate the exterior of a food and cook it from the inside—unlike old-school ovens that cook from the outside in.

Popsicle
In 1905, 11-year-old Frank Epperson of Oakland, Calif., mixed some sugary soda powder with water and left it out on a cold night. The concoction froze—and proved delicious when he licked off the wooden stirrer. Epperson, who died in 1983, dubbed his accidental treat the Epsicle and later patented it, but he sold the rights in 1925.

Velcro
One day in 1941, George de Mestral took his dog for a walk in the Swiss woods. Later he noticed burrs stuck to his pants—which refused to be removed. Under a microscope, de Mestral saw that the burrs had tiny hooks that attached themselves to thread loops in his pants. Sensing a business opportunity, he connected with a Lyon fabric manufacturer and named the product with a portmanteau of "velvet" and "crochet"—French for *hook*.

Slinky
At the height of World War II, a mechanical engineer named Richard James was trying to devise springs that could keep sensitive ship equipment steady at sea. After accidentally knocking some samples off a shelf, he watched in astonishment as the springs gracefully "walked" down instead of falling. Boom: teaming with his wife, Betty, James developed a plan for the next big novelty toy.

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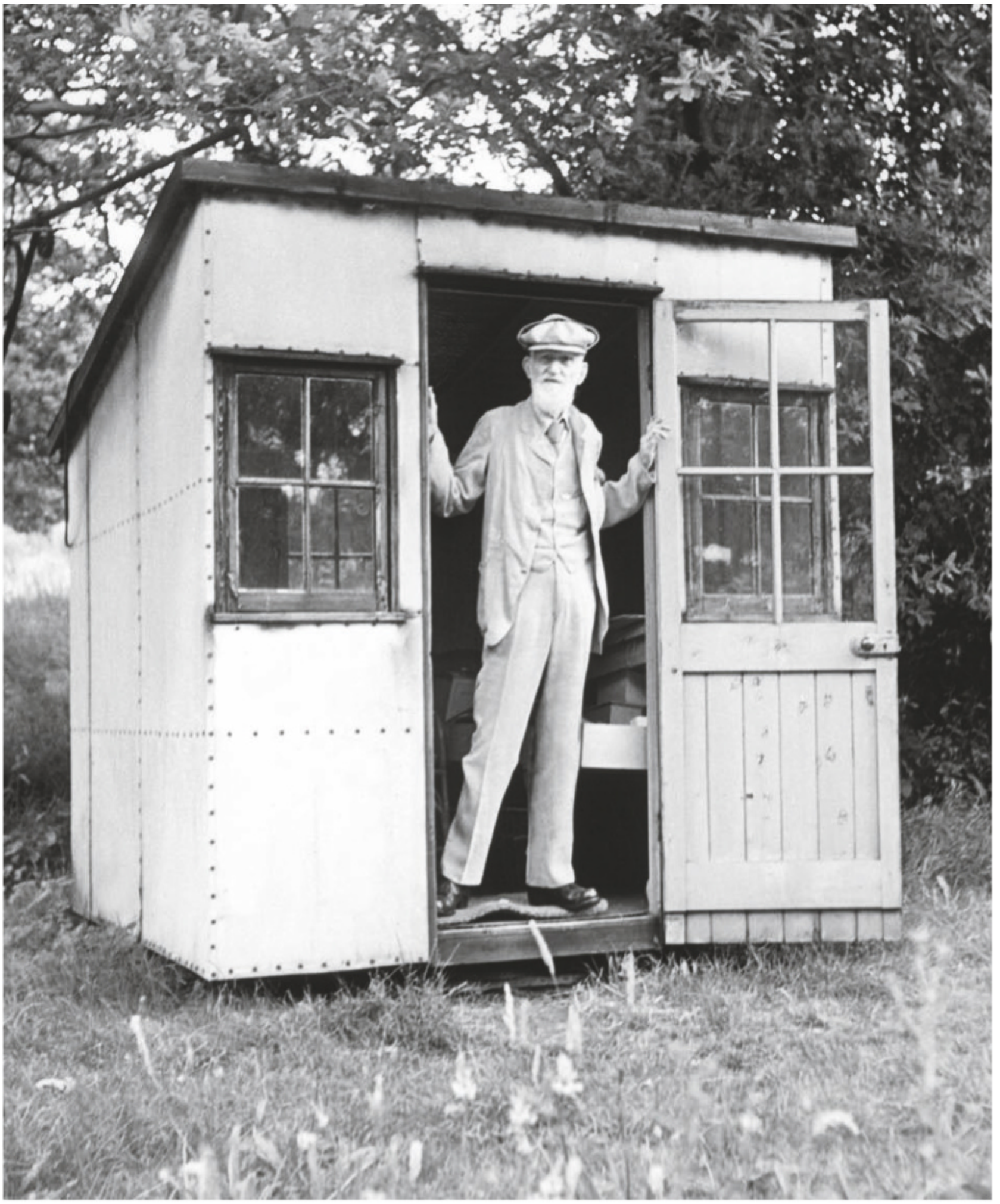

HOW SHAW FOLLOWED THE SUN

In the garden of George Bernard Shaw's Hertfordshire, England, home, the Irish playwright constructed a writing hut where he worked for the last two decades of his life (1856–1950). It was built on a turntable, *Modern Mechanix* magazine explained in 1929, "so when the morning sun shifts, he merely places his shoulder against the side of the hut and gives it a push so that the warming beams fall through his window at the correct angle."

From ancient drawings to the genius of Leonardo and Einstein to the imagination that colors our everyday life: the drive to create, innovate and make something new is a big part of what makes us human.